FACTORS THAT INFLUENCE CRITICAL CHAIN PROJECT MANAGEMENT

IMPLEMENTATION SUCCESS

Approved: Date: 6/28/12
Scott Wright, Ph.D., P.E., PMP Committee Chair

Approved: Date: 6/21/12
Barb Barnet, Ph.D. Committee Member

Approved: Date: 6/21/12
Larry Leach, PMP Committee Member

Approved: Date: 6/27/12
Michael O'Connor, PMP Committee Member

FACTORS THAT INFLUENCE CRITICAL CHAIN PROJECT MANAGEMENT

IMPLEMENTATION SUCCESS

A Thesis

Presented to

The Graduate Faculty

University of Wisconsin-Platteville

In Partial Fulfillment

Of the Requirement for the Degree

Master of Science in Project Management

Student's Program

By

Lisa M. Repp

June 11, 2012

ACKNOWLEDGEMENTS

Thank you to everyone who has supported me in writing this thesis. This includes family, thesis committee members, University of Wisconsin-Platteville advisors and staff, and all survey and interview participants.

First and foremost, this thesis would not have been possible without the ongoing support of my family, especially my husband Brandon. He rearranged his schedule to ensure that I had time to work on my thesis and was a valuable asset in which to turn for editing advice. Anders, Ellie, and Nicole also deserve thanks for letting me work at the computer uninterrupted, which is a big sacrifice for a four, two, and one-year-old.

I am so grateful to have such a knowledgeable, supportive thesis committee.

- Dr. Scott Wright, as my thesis supervisor, deserves thanks for accepting the challenge of supervising his first master's thesis student and doing so within such a tight timeframe. He has provided excellent advice, been quick to respond to my inquiries, and provided detailed feedback on my work.
- Larry Leach's insight into the topic was invaluable in helping to ensure that critical chain concepts were accurately portrayed. He always made time to answer my questions and was patient with me as I encountered a steep learning curve for critical chain concepts. I also appreciated his assistance in connecting me with interview participants.
- Michael O'Connor was very supportive and provided me excellent perspectives about critical chain from an industry user vantage point. He was very prompt in reviewing my work and answering my inquiries, in addition to providing contacts for survey pilot testing and potential interviews.
- Dr. Barb Barnet was very helpful in providing statistical advice for data analysis. Even though she joined the committee mid-stream, she was very supportive of the topic and provided excellent advice to ensure robustness of my data analysis.

Finally, none of the results achieved in this thesis would have been possible without the participation achieved in both the survey and interview process. I am very grateful to everyone who sacrificed their time to provide their own personal experiences related to critical chain project management.

Even though I do not have personal experience using critical chain concepts myself, I believe that critical chain project management can create a better work environment through the elimination of multitasking, and desire to work in an environment that uses critical chain concepts in the future. My hope in completing this thesis is that by analyzing literature and critical chain implementation experiences, future implementers of critical chain project management will have information available to increase the chance of critical chain project management implementation success. Thank you to all the organizational leaders that have taken or will take the risks to implement the critical chain project management methodology.

FACTORS THAT INFLUENCE CRITICAL CHAIN PROJECT MANAGEMENT IMPLEMENTATION SUCCESS

Lisa M. Repp
Under the Supervision of Dr. Scott Wright

Statement of the Problem

Research shows that there are no comprehensive structured investigations to determine what factors influence the success of a critical chain project management (CCPM) implementation. There are also no publications that collectively identify all factors related to CCPM implementation success. Each existing study or publication has not addressed all factors related to CCPM implementation in terms of pre-existing conditions in an organization, established goals for the CCPM implementation, features of CCPM that are implemented, factors related to change management, and factors specific to CCPM.

In addressing the above research problem, this study identifies all known significant factors that can affect CCPM success rate and tests for their impact as analyzed from survey and interview participants' CCPM implementation experiences.

Methods and Procedures

All factors that could potentially influence the outcome of a CCPM implementation were identified via deduction. These factors were then included in a survey targeted at people that have had CCPM implementation experiences. The survey was distributed to the Project Management Institute (PMI), PMI Scheduling Community of Practice, CriticalChain Yahoo! Group, CriticalChain and Critical Chain Professional LinkedIn Group, and forwarded for distribution to clients of critical chain software companies. Participants were also encouraged to forward the survey link to their professional contacts with critical chain experience. The survey data was collected and analyzed to draw conclusions about which factors influence CCPM implementation outcomes.

Interviews were conducted to substantiate the comprehensive nature of factors identified in the survey. Interview participants were recruited from survey participants described above in addition to contacts provided by thesis committee members. Interview data was collected and analyzed and to identify additional factors that may not have been addressed in the survey.

Summary of Results

The number of completed survey responses (eighty-six from the targeted group) was sufficient to use statistical analysis techniques to draw some preliminary conclusions. However, the quantity of low-success implementations (twenty), when compared to high-success implementations (sixty-six), is significantly lower. Therefore, survey findings are representative

of participants completing the survey only and not necessarily of the entire population of CCPM implementations. Further research needs to be conducted to validate results from this study.

Survey findings indicate that the presence of factors is differentiated between high-success and low-success experiences for multi-project and single-project CCPM implementations. For multi-project CCPM implementations, thirteen factors were identified as having differences in median values between high-success and low-success implementations that were statistically significant with the largest number of significant factors residing in the CCPM features factor group. For single-project CCPM implementations, forty-one factors were identified as having differences in median values between high-success and low-success implementations that were statistically significant with the largest concentration of significant factors residing in the change management factor group. Where possible, multi-project and single-project implementations were combined to determine that eighteen factors had differences in median values between high-success and low-success implementations that were statistically significant; the largest number of significant factors resides in the goals established for CCPM factor group and CCPM features factor group.

The low-success multi-project implementations were similar to high-success implementations in many aspects such that many features were highly implemented and attention was given to using good change management practices. Therefore, the slight differences between high-success and low-success multi-project implementations reveal factors that can be detrimental to success even when there is a concerted effort to do everything right. One such detrimental factor was the presence of resistance to the implementation. Low-success single-project implementations, conversely, were characterized as having low levels of CCPM implemented features, low usage of change management techniques, and a belief that the CCPM method was "too complex." The comparisons between high-success and low-success single-project implementations, therefore, revealed numerous factors such as goals, CCPM features, and change management techniques that are most essential to achieving success.

Ten interviews were conducted as part of the study. The interviews revealed fourteen new potentially significant factors, twelve of which were common amongst two or more interviewees. The emergence of these new factors suggests that there are other potentially significant CCPM factors that may not be represented in the survey and interview combined. Further research may be able to identify other factors that can contribute to CCPM implementation success.

The survey (via comment boxes) and interview process combined identified new factors to be included in future research into CCPM implementations. The interviews also identified the need for researching sustainment of CCPM in an organization, instead of focusing solely on the implementation. One key factor in such research would be the impact of organizational structure on the sustainment of CCPM in an organization.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Table Page

Table Page

CHAPTER 1

INTRODUCTION

Critical chain project management (CCPM) methodology was introduced as a new schedule planning, monitoring, and controlling process in 1997 through Eliyahu Goldratt's book *Critical Chain*. Any organization adopting this relatively new methodology hopes to capitalize on the opportunity to significantly reduce project completion times. By completing this research on factors that influence CCPM implementation success, the researcher (1) deduces factors, (2) tests the significance of these factors through surveys and interviews, and (3) draws conclusions from the collected data regarding which factors have the greatest influence on CCPM implementation success. Previous studies related to factors, or critical success factors[1], that contribute to successful implementations are limited in nature; this research furthers these studies by providing a structured comprehensive assessment of CCPM implementation factors.

Purpose of the Study

Previous studies about CCPM implementations available to the researcher are limited to conference proceedings, select case study reviews as a dissertation and PowerPoint presentation, and lessons-learned documents. None provide a structured comprehensive assessment of all factors that can influence CCPM implementation success. Table 1-1 below summarizes the content of previous CCPM implementation publications. The purpose of this study is to thoroughly review the literature available about CCPM to deduce the factors that may influence CCPM implementation success. These factors are categorized in terms of pre-existing conditions

[1] Pinto and Slevin (1987) noted that any factors that can affect CCPM implementation success can be considered critical success factors (CSF's), namely "factors which, if addressed, significantly improve project implementation chances" (as cited by Amberg et al., 2005, p. 1). This research uses simply the term "factor" to describe any factor that can potentially impact CCPM implementation success.

in an organization, established goals for the CCPM implementation, features of CCPM that are implemented, factors related to change management, and factors specific to CCPM. Pre-existing conditions receive little attention in CCPM literature but, as noted by Rockart (1979), environmental conditions and business characteristics need to be addressed to provide a comprehensive assessment of factors that can influence implementation success (as cited by Amberg et al., 2005, p. 1).

Table 1-1
Summary of CCPM implementation publications

			Extent of discussion on CCPM implementation factors in regard to:				
Publication	Publication Type	Topic	Pre-Existing Conditions	Established Goals for CCPM	Features of CCPM Implemented	Change Management Factors	CCPM-Specific Factors
Simpson & Lynch (1999)	Conference Proceedings	Informal investigation of CCPM critical success factors	Some	Some	Some	Some	Some
Lechler, Ronen, & Stohr (2005a)	PowerPoint Presentation	Case study review of a positive and a negative CCPM implementation	Some	Some	Some	Some	Some
Casey (2005)	Dissertation	Findings from six CCPM implementation case studies		Some	Some	Some	
Realization (2004; 2005; 2006; 2007; 2008; 2009; 2010)	Publicly-Shared Company Lessons-Learned Documents	CCPM lessons learned from Realization's yearly Project Flow conferences		Some	Some	Some	
Peterson, Oliver, & Webb (2002)	Conference Proceedings	Discussion on change management for implementing CCPM or EVM		Some		Some	

Note. CCPM and EVM (Earned Value Management) are both considered advanced project management concepts (Peterson et al., 2002, p. 1).

This study produces a comprehensive list of potential factors that can affect CCPM implementation success from the publications in Table 1-1 and other critical chain publications. A survey was developed from this list of potential factors and is used to determine which of the identified factors have the greatest influence on successful implementation of CCPM. Amberg, Fishcl, and Wiener (2005) stated, “Decision makers might win insight on their perceptions in regard to both truly relevant success factors and those which are only perceived as such” (p. 5). Understanding influential factors for CCPM implementation success, from a comprehensive assessment, provides valuable information for decision makers involved in future CCPM implementations. Furthermore, Amberg et al., (2005) identified the following advantages of indentifying factors that can influence CCPM implementation success:

> The process helps the manager to determine those factors on which he or she should focus management attention. It also helps to ensure that those significant factors will receive careful and continuous management scrutiny.…The identification of [influential success factors] moves an organization away from the trap of building its reporting and information system primarily around data that are ‘easy to collect.’ Rather, it focuses attention to those data that might otherwise not be collected but are significant for the success of the particular management level involved. (p. 7)

Method of Approach

A survey, using the factors identified from the literature review, provided data for conclusions about which factors influence CCPM implementation success. The content included in the survey was validated using the following methods:

1) deduction, which was used in the literature review to determine all relevant CCPM implementation factors;
2) subject matter experts’ examination of the literature review to ensure all relevant CCPM implementation factors were identified (two subject matter experts are included as part of the thesis committee);

3) pilot testing for the survey, ensuring that CCPM implementation factors were clearly represented and that data gathered from the survey was useful; and
4) interviews to ensure that significant CCPM implementation factors were not overlooked. Interview participants were also asked to complete the survey at the conclusion of the interview to allow the survey results to be combined with interview data for a complete assessment.

The above approach provided data that could be analyzed to determine (1) which factors influence the success rate of critical chain methodology implementations and (2) that all factors that influence critical chain implementation were included in the study. The research findings reveal that factors from all five factor groups can impact implementation success based on statistically significant differences in medians for the presence of each factor between high-success and low-success implementation experiences. Additionally, fourteen new factors that potentially impact CCPM implementation success were identified from the interviews.

Assumptions

There are two main assumptions for this study.

1) The survey used in this study was developed by conducting a thorough review of the literature on CCPM methodology, subsequent subject matter expert review, and pilot testing of the initial survey. An assumption was made that the survey adequately addressed all success factors related to implementation of CCPM methodology. This assumption was false because comments from the survey and the interviews revealed new factors that were not addressed in the survey. Further research will be needed to investigate the impact of the newly identified factors.

2) The comment boxes in the survey and use of interviews was assumed to be adequate for validating (or invalidating) that all factors have been addressed in this research. These methods were adequate to show that the first assumption was false.
3) An assumption was made that the survey and interview process captures a representative sample of CCPM implementation cases. The population of CCPM implementation cases is unknown but assumed to be one million or less. At a population of one million, a sample size of 383 would have sufficed to show at a 95% confidence level that the sample was representative (How Statistically Valid, n.d., p. 2).
    - Surveys were posted in a variety of locations and forwarded to contacts at companies that implement CCPM software solutions (for distribution to their client lists) for the purpose of capturing as many CCPM implementation experiences as possible.
    - Interview participants were chosen based on availability and connections made through various networking methods. Interviews were conducted on a voluntary basis and participants were not randomly selected.

    There were not enough responses for the survey (86 valid responses) and interviews (ten interviews) combined to show that this assumption is true. Due to the lower than necessary number of responses, results from this study are based on the experiences shared by survey and interview participants only and may not be representative of all CCPM implementation experiences.

Delimitation of the Study

There are three key limitations of this study.

1. Obtaining an adequate number of responses for the survey was challenging. An additional challenge was getting enough responses for different types of implementations

(multi-project and single-project) in addition to a balance of high-success and low-success implementations for statistical interpretation of the survey responses. Conclusions drawn are limited to CCPM implementers with similar experiences as those who took the survey and not necessarily indicative of the population of people or types of organizations that have attempted to implement CCPM. Data describing that population does not currently exist.

2. Obtaining a representative sample of interviewees from the survey respondents, particularly those representing low-success implementations, was challenging. A total of ten interviews were conducted. The interviewees represented high-success and low-success implementation experiences between multi-project and single-project implementations. Data gathered from the interviews was used to enhance identification of factors influencing implementation of CCPM. No conclusions are drawn solely from the interviews.
3. Survey responses were gathered and interviews were conducted over a timeframe of approximately two months. Participation within this timeframe may have been limited to a subset of otherwise potentially valuable sources of data.

Organization

The remainder of this thesis will be organized as follows: literature review, research emphasis and objectives, methodology, findings, conclusions and recommendations, references, and appendix. The appendix provides a list of acronyms, a description of critical chain concepts, the survey questions, and the consent form used for the interview process.

The literature review provides the reader with relevant background information and definitions for critical chain methodology. Published success stories demonstrate the potential of the methodology and introduce the questions that will be used to deduce factors that can potentially influence the implementation of CCPM. The deductive technique is exploited to investigate CCPM methodology in terms of the following: time management as a project success factor for CCPM, significance of time management relative to cost performance for CCPM, significance of CCPM implementation challenges, CCPM as an unnecessary solution for critical path method, and the potential weaknesses of the CCPM methodology.

The research emphasis presents questions relevant to the five groupings of factors that were derived from the literature review in relation to the CCPM methodology, namely the following: pre-existing organizational conditions, organizational goals when pursuing implementation, features actually implemented, factors related to change management, and factors related specifically to the CCPM methodology. The results of the research are used to answer the following question: What factors influence critical chain project management implementation success? This can be used by decision makers to improve the chances of success in future CCPM implementations and subsequently serves as the research objective.

The methodology section describes the approach used to determine factors that can influence critical chain methodology implementation success. This includes a description of how the survey was developed, administered, and analyzed, and how the interviews were conducted and analyzed. The findings section provides results from both the survey and interviews and their subsequent analysis. The conclusions and recommendations section draws conclusions from the analysis of the surveys and interviews and provides some insight for further research.

CHAPTER 2

LITERATURE REVIEW

In 1997, Goldratt introduced critical chain concepts, extending the application of his Theory of Constraints into the project environment, in his book *Critical Chain. Critical Chain* was presented as a business novel, so publications soon followed to provide a greater understanding of how the critical chain concepts can be applied to single-project and multi-project environments. These included Gray, Felan, Umble, and Umble (2000); Leach (1998), (1999), & (2000); Patrick (1999a), (1999b); Rand (2000); and Umble & Umble (2000) to name a few (a full description of critical chain concepts can be found in Appendix B). Literature addressing the factors that influence the success rate of implementing the critical chain methodology have been limited to a few studies, including Simpson and Lynch (1999), Casey (2005), Lechler et al. (2005a), Realization (2004; 2005; 2006; 2007; 2008; 2009; 2010), and Peterson, Oliver and Webb (2002). These publications, along with literature available on critical chain concepts, are explored to deduce potential factors relevant to successfully implementing critical chain concepts. The potential factors include (1) characteristics of the organization before attempting critical chain implementation, (2) goals related to implementing critical chain, (3) specific features of critical chain that are implemented, (4) factors related to the change management process involved in implementing critical chain, and (5) factors directly attributed to challenges associated with critical chain concepts.

Background and Definitions

One of the stages in project planning is to fully develop a work breakdown structure (WBS) to adequately describe all deliverables in a project, assign resources to tasks (or activities), estimate costs and duration to complete each task, and then schedule the tasks so that project work can be completed (Project Management Institute, 2006). The schedule provides an estimated completion date based on completion of all tasks that comprise a project. Once the schedule is in place and project work commences, monitoring schedule progress also becomes important (Project Management Institute, 2008). Deviations from the project schedule can and do occur, so management needs to be able to understand the implications of these deviations and control them accordingly to finish the project by the scheduled completion date (Project Management Institute, 2008).

The basic schedule planning, monitoring, and controlling processes are used in the traditional critical path method as well as the newer critical chain project management. The following terms must be defined: critical path, critical path method, critical chain, and critical chain project management.

- The *critical path* is the longest link of sequential tasks that determines a project's completion date on a schedule, where delays in the critical path will delay the whole schedule (Project Management Institute, 2008).
- *Critical path method* (CPM) is the method used for planning, monitoring, and controlling the schedule based on the established critical path (Project Management Institute, 2008).
- The *critical chain* is the longest link of sequential tasks taking into consideration resource constraints (not necessarily true for the critical path) where the project's completion date is determined only after a project buffer has been added to the end of the critical chain (Project Management Institute, 2008).
- *Critical chain project management* (CCPM), as coined by Larry Leach in 1998, is the project schedule planning, monitoring, and controlling method that uses the critical chain,

first for schedule planning by establishing the critical chain and buffers, and then for monitoring and controlling the project schedule in terms of the buffers (Leach, 2005).

Alternate terms have been used in the literature for CCPM, such as critical chain (CC) (Goldratt, 1997), critical chain method (Project Management Institute, 2008), critical chain scheduling (CCS) (Yang, 2007), and critical chain scheduling/buffer management (CCS/BM) (Herroelen, Leus & Demeulemeester, 2002). Along with these alternate terms, there are alternate understandings of critical chain concepts, especially regarding the lack of integration of these concepts into all aspects of the project planning, monitoring, and controlling processes (Leach, personal communication, January 25, 2012). In this paper, both CPM and CCPM are meant to include the integration of other Project Management Body of Knowledge (PMBOK®) knowledge areas[2] beyond just project time management to provide equivalent comparisons between each method and support the successful execution of each method as an all-encompassing solution for schedule planning, monitoring, and controlling processes (Leach, 2005; Leach, personal communication, January 25, 2012). Both CPM and CCPM need the supporting PMBOK® knowledge areas for execution of a successful project (Leach, personal communication, January 25, 2012). One notable difference is that CPM uses the schedule deadlines for monitoring and controlling project progress, while CCPM uses buffer management for these same processes (Leach, personal communication, January 25, 2012).

Another significant difference between CPM and CCPM is that CPM is used on an individual, single-project basis, while CCPM can be used as a multi-project scheduling solution in addition to its applicability for use on an individual, single-project basis (Lechler, Ronen, &

---

[2] The nine PMBOK® knowledge areas include project integration management, project scope management, project time management, project cost management, project quality management, project human resource management, project communications management, project risk management, and project procurement management (Project Management Institute, 2008, p. 67).

Stohr, 2005b, p. 48). Figure 2-1 below is the author's interpretation of CPM and CCPM in relation to being single- and multiple-project solutions.

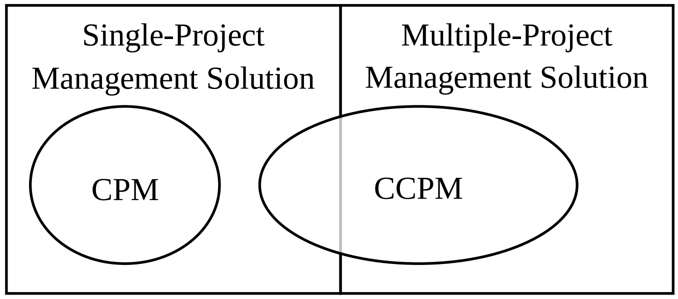

Figure 2-1. PMBOK® in relation to CPM and CCPM

For multi-project organizations utilizing CPM, CPM is used the same way for each individual project without consideration for how the individual projects are connected in the organization (Lechler et al., 2005b, p. 48). Lechler et al. (2005b) stated, "The focus in CP[M] on efficiency of single projects leads to local, rather than global, optimization in multi-project situations" (p. 48). For a multi-project situation, an organization may use a multi-project resource planning tool; however, portfolio balancing tools do not feedback directly into individual CPM schedules (Leach, personal communication, February 17, 2012). Therefore, shared resources among projects in a multi-project CPM situation may be assigned tasks from more than one project at any given time. This creates a situation where resources choose to multitask to show progress on multiple projects simultaneously (Lechler et al., 2005b, p. 55). Patrick (1999b) described the following scenario in regard to multitasking:

> If a resource divides her attention between different tasks before handing off task deliverables, all the projects involved will take longer than necessary because all of that resource's successors from each project will have to wait longer than necessary due to time spent on other project work. And if many resources in the organization become accustomed to working in this manner, then most projects will take significantly longer

> than necessary, in both their promise and their execution. The projects will also be impacted by the variability of not only their own tasks, but also of those associated with the other projects that are interleaved within them. (p. 1)

CCPM, like CPM, can be applied to a single project but, unlike CPM, can be applied as a solution for prioritizing projects in a multi-project environment, while still focusing on completing each staggered project as efficiently as possible (Lechler et al., 2005b, p. 48). Whether implemented as a single-project or multi-project solution, CCPM creates an environment where focused work is possible, without resources believing there is a need to multitask. If CCPM is applied to a single project, the project must have very distinct features, the most important of which is limited exposure of the project team to outside distractions beyond the project work, i.e., a dedicated project team, to make the elimination of multitasking possible (Milosevic, 2003, p. 206). For the same reason, the multi-project application of CCPM is not feasible unless all projects are scheduled using CCPM (Goldratt as cited by Cabanis-Brewin, 1999, p. 50). Lechler et al. (2005b) noted that "a unique contribution of CC[PM] is the guidance it provides for improving performance in situations where multiple projects share scarce resources" (p. 48). (For more discussion about multitasking in relation to CCPM and discussion about critical chain concepts, see Appendix B[3].)

Critical Chain Usage

Users of CCPM claim to see significant improvements in the form of reduced schedules and increased on-time schedule completion. The following are a few examples:

[3] The author places the critical chain concepts in the appendix so that the literature review section of the paper can focus on deducing the factors that influence critical chain project management (CCPM) implementation success. All readers unfamiliar with CCPM concepts are encouraged to review Appendix B to gain understanding before reading further.

- Hagemann (2001) described how the Langley Research Center, NASA, implemented CCPM in wind tunnel test cycles and realized increased project scheduling performance, productivity gain of 50%, and improved team morale (p. 4.B.1-10). Increased project scheduling performance was measured by the ability to complete the same amount of tests in 1999 as Langely Research Center had in 1997, but with half the personnel as in 1997 (Hagemann, 2001, p. 4.B.1-10). Hagemann (2001) also reported the improvement in morale by explaining a change in vacation policies where, with the implementation of CCPM, “the Facility Manager was routinely able to permit as much as half of his workforce to be away from the facility during any given week” (4.B.1-10). This was in comparison to “[people in] the wind tunnel test community… [having] great difficulty finding time to take their vacations” before the implementation of CCPM (4.B.1-8).
- Best and Srinivasan (2006) explained how the Warner Robins Air Logistics Center implemented CCPM to realize a reduction in the number of days required to repair and overhaul C-5 Galaxy aircraft (from 240 days to 160 days within eight months) (p. 47).
- Gupta (2005) reported how a North American manufacturer of household appliances (unnamed) implemented CCPM in a multi-project environment and was able to increase “its NPD [new product development] from 34 to 52 new products introduced in the first year and to 70-plus products introduced in the second year with no increase in head-count. Furthermore, the number of projects coming in on-time increased from 74 percent to 88 percent” (pp. 30-31). As of 2005, the company achieved an overall increase in throughput of new product development projects by 70% (Gupta, 2005, p. 35).

In addition to publications reporting positive results from implementing CCPM, some of the largest companies that provide CCPM software reported the results achieved by a selection of clients (AGI-Goldratt Institute, n.d.; ProChain Solutions Inc. n.d.; Realization n.d.). These reported successes are not limited to one industry or type of project environment and the CCPM methodology achieves results regardless of software solution utilized. Lechler et al. (2005a) reported a multiple case study review of the results achieved using CCPM, noting the following percentages of overall improvement:

- Increased systems throughput ~ 20%
- Reduced project schedules ~ 15% - 45%
- Increased on-time delivery ~ 93%
- Reduced backlog ~ 30% - 70%
- Reduced overtime ~ 20% - 50% (Slide 18)

In light of these reported findings, the following questions can be developed:

- If the application of the CCPM methodology achieves such positive results, why aren't more organizations using CCPM (Lynch, 2003, p. 2)?
- Do all CCPM implementations achieve positive, predictable results?
- If not, what are the relevant factors that indicate a CCPM implementation will be successful?

Although results have indicated success, there has been no complete study conducted across different industries and project environments to collect relevant common factors that determine what is significant in achieving success using CCPM. Below is a summary of those studies that have been conducted.

- Simpson and Lynch (1999) gathered interview data and informal feedback to develop an initial set of critical success factors for the implementation of CCPM but "make no claim that…[the] findings are conclusive…[and, instead, are meant to] be treated as first-round findings and…serve, perhaps, as hypothesis to guide future more formal and structured investigations of CCPM" (p. 2).

- Lechler et al. (2005a) reviewed case studies of a successful CCPM implementation (Case Study ABC Ltd.) and an unsuccessful implementation (Failure Case Company "T") and reported lessons learned and potential success factors related to the success/failure of CCPM implementations. Lechler et al.'s (2005a) study was limited in scope and, therefore, unable to reveal implementation factors across all CCPM implementations.
- Casey (2005) completed a dissertation on the study of multiple CCPM project implementations. While this study did reveal some possible implementation factors, the study covered only six CCPM implementations, all of which took place in the same organizational setting.
- Realization (2004; 2005; 2006; 2007; 2008; 2009; 2010) shared lessons learned documents as reported from Realization's yearly Project Flow conferences, in which Realization customers shared CCPM implementation experiences. Realization's lessons-learned documents provide a summary only and are limited to experiences shared amongst Realization customers.
- Peterson, Oliver and Webb (2002) approached the behavioral change strategies needed to implement advanced project management practices such as Earned Value Management (EVM) and CCPM (p. 1). The factors that affect a successful implementation of CCPM were covered in general, in terms of change management, and did not cover implementation factors specific to CCPM methodology (Peterson et al., 2002).

Overall, each of the publications listed above cover only some of the potential success factors, and none are comprehensive in nature. Both Casey (2005) and Lechler et al. (2005a) discussed failed CCPM implementations and this evidence provides an answer to the second question: not all CCPM implementations achieve positive, predictable results. Lechler et al. (2005a) also noted that "several CC implementation failures are known but not published!" (Slide 36). Therefore, the remaining two unanswered questions posed above will be explored in the aforementioned cited literature, as well as additional literature that is available on critical chain, which includes the following: publications that describe the concepts and use of CCPM, publications that explore specific aspects of CCPM methodology, publications that explore weaknesses of CCPM, and publications that describe specific successes and failures. After gaining a better understanding as to why CCPM is not more widely used and what factors are pertinent to successful CCPM implementations, a survey can be developed to test the relevance of these factors on CCPM implementation success.

Deductive Technique

A deductive approach can be used for survey item identification using the extensive literature review of factors that can potentially affect CCPM implementation. According to Hinkin (1998), "this approach requires…a thorough review of the literature to develop the theoretical definition of the construct under examination" (p. 106). Disadvantages of using the deductive approach include its very time-consuming nature and the possibility of it not being well-suited for exploratory research, as the method might "impose measures onto an unfamiliar situation" (Hinkin, 1998, p. 107). This study is not an exploratory study and instead uses information from previous studies, including those by Simpson and Lynch (1999), Casey (2005), Lechler et al. (2005a), and Oliver and Webb (2002), as well as other critical chain publications, to build a list of factors. Another disadvantage of using the deductive approach, according to Hinkin (1998), is the need for the researcher to "possess a working knowledge of the phenomena under investigation" (p. 107). While the researcher does not possess this working knowledge, the extensive literature and participation of thesis committee members that do possess working knowledge ensured that the list of factors for survey items was complete.

The main advantage of using the deductive approach is that "if properly conducted, it will help to assure content validity in the final scales" (p. 107). Subject matter experts, including two members of the thesis committee with first-hand experience using CCPM, evaluated the factors for content validity. In addition, the survey pilot test review by critical chain industry users provided suggestions and comments about the included factors. Hinkin (1998) noted that "it is not possible to measure the complete domain of interest, but that it is important that the sample of items drawn from potential items adequately represents the construct under examination" (p. 105).

Hinkin (1995), in a review of survey development items using the deductive approach, discovered that "it was frequently not reported how items were generated or derived, if they were theoretically based, or if they had been pretested to assess content validity in any way" (p. 970). To ensure clarity about survey item generation in this research, the source of the items included in the survey are thoroughly discussed to provide their basis in literature and tracked using endnotes which are alphabetically superscripted throughout the chapter. There is a brief description linking each endnote item to the survey at the end of this chapter. Researching the reason why all organizations are not using CCPM , in reference to one of the questions above, will be used as a basis for the deductive technique to determine the relevant factors that may influence CCPM implementation success. There is limited information about failed CCPM implementations, but information from failures will be integrated when possible to demonstrate factors that should be considered.

Why Isn't CCPM Used in All Organizations?

Besner and Hobbs (2006; 2008) found in two survey-based studies on the use of all types of project management practices that "critical chain method and analysis" gets "less than very limited use" (p. 40; p. 20). Besner and Hobbs (2008) partially attributed low usage to the newness of critical chain (p. 21). However, only 13% of respondents were not familiar with the method (with the assumption that no opinion represents lack of knowledge of the tool) (pp. 21-22). Besner and Hobbs (2008) also found that CCPM was reported by survey participants to be not applicable only 21% of the time (pp. 21-22). Therefore, according to what Besner and Hobbs (2008) reported, many project practitioners have knowledge of CCPM but are not using the method. From the discussion above regarding the concepts of CCPM and industry results, there are advantages over the traditional CPM in achieving improvements in project durations. Why, therefore, is the method not being widely used? One answer might be that the method is not well known[A], and that people responded in the survey as if they were familiar with the critical chain concepts when in reality they were not.

CCPM's limited use may also be attributed to varying definitions and terminology[B]. The Besner and Hobbs (n.d.) survey defined terms to differentiate CPM and CCPM (p. 9). Even with a provided definition as shown in Table 2-1, some people may have alternate views on the application of CCPM and may not be able to view the method as distinct from CPM.

Table 2-1
Differentiation of critical path method and critical chain method in Besner and Hobbs survey

Critical chain method & analysis	Analysis of the task network to determine the longest path considering task constraints combined with resources' constraints and the management of that path.
Critical path method & analysis	A network analysis technique used to predict project duration by analyzing which sequence of activities (which path) has the least amount of scheduling flexibility (the least amount of float). (PMBOK Guide)

Note. The above definitions were provided to survey participants in the Besner and Hobbs (2008) study and are replicated here from Besner and Hobbs (n.d.) (p. 9).

Despite these reasons, if the assumption holds true that only 13% of survey respondents (as stated above) are not familiar with the concepts of CCPM, then there may be alternative reasons as to why the method is not being widely used. The following potential reasons will be further explored to help determine what factors are important to consider in an organization's decision to pursue CCPM as a schedule planning, monitoring, and controlling solution:

- First possibility: Improving project time management (schedule planning, monitoring, and controlling) processes through the use of CCPM may not be highly valuable in all project environments.
- Second possibility: Cost management is the factor that organizations are focusing on instead of time management. Additionally, improving project time management (schedule planning, monitoring, and controlling) processes through the use of CCPM might not be justifiable in terms of project cost performance.
- Third possibility: Though many project practitioners are knowledgeable of CCPM (an assumption based on the survey results by Besner and Hobbs (2008)), once the project practitioners have investigated implementation of CCPM or initiated implementation efforts, they become discouraged by the challenges of implementing CCPM and no longer pursue the effort.
- Fourth possibility: Organizations and project practitioners do not see value in attempting to implement CCPM as a solution due to the belief that the current traditional use of CPM is not problematic. Along with this reasoning, project practitioners may believe that CCPM has nothing new to offer over the traditional CPM (Duncan, 1999; Filatraut & Peterson, 2000; Triestch, 2005; Uyttewaal, 1999; Wilkens, 2000).

First Possibility: Time Management as a Project Success Factor

One possible reason for CCPM's limited use is the idea that schedule planning, monitoring, and controlling tools may not have much value in the project environment. In a study by Zwikael (2009), project time management was ranked as the most significant knowledge area to contribute to project success, based on the nine areas of Project Management Body of Knowledge (PMBOK®) (p. 98). When further analyzed across six industry types, project time management had more significance (ranked one or two out of nine) in four industry types (software, communication, services, and government) and less significance (ranked six or seven out of nine) in construction/engineering and production (p. 101). This demonstrates that project time management and scheduling methodologies are important but there may be other factors, such as industry type[C], that might explain low usage of processes such as CCPM to improve schedule performance.

Goldratt (1997) addressed the idea that scheduling may not be as significant in construction projects where contracts are not designed to provide incentives for contractors to finish ahead of schedule (p. 196). Goldratt (1997) elaborated that this does not mean that the buyers of construction services do not want projects to be completed in shorter durations and may even pay a premium to contractors that can complete construction projects in less time than under schedules planned using CPM (p. 201). Goldratt noted that another way to make faster project completions financially beneficial is by "relentlessly reducing lead times and training…salespeople to sell early completion bonuses" (as cited by Realization, 2006). Although time management may not be recognized as a top priority in the construction industry, construction projects have seen improvements using CCPM. Habitat for Humanity, a charity that constructs houses through the use of volunteers, demonstrated the applicability of CCPM to construction projects and "built a four-bedroom house in New Zealand in three hours, 44 minutes and 59 seconds, using Critical Chain [CCPM] to shave nearly an hour off the previous record" (Cabanis-Brewin, 1999, p. 50). Sood (2003) reported that Shea Homes, a residential building general contractor, uses CCPM to coordinate work with the more than 50 trade partners that actually construct the houses and have reduced the building cycle time from 91 days to just 49 days (p. 58).

Production projects may also be less focused on project time management, as indicated by a study conducted by Zwikael (2009). The lack of emphasis on project time management may be due to projects in production environments being comprised of team members with non-project responsibilities that are prioritized higher than project responsibilities. Some production applications, however, are able to use CCPM concepts in areas such as turnaround planning (where production facilities shut down operations to conduct maintenance, modifications, and/or installations) (Bevilacqua, Ciarapica, and Giacchetta, 2009; Gupta, 2011). Production facilities can limit multitasking when the facility is shut down, as opposed to normal operations, when production employees need to be able to focus on production activities in addition to any project responsibilities. Gupta (2011) and Bevilacqua, Ciarapica, and Giacchetta (2009) demonstrated that production turnaround projects can be successfully scheduled using CCPM. However, projects that run concurrently with production-related responsibilities may remain an issue for the applicability of CCPM with limited ability to control levels of multitasking on a daily basis. According to Leach, the next advances related to CCPM involve integrating CCPM in environments where production or other responsibilities take away the attention of project participants through the use of lean methods in conjunction with CCPM (Leach, personal communication, January 17, 2012). The presence of non-project responsibilities[D] and the integration of lean methods[E] with CCPM may be relevant factors related to the success of CCPM implementations.

Second Possibility: Time Management Relative to Cost Performance

A second possible reason that CCPM is not widely used is that although Zwikael (2009) demonstrated the importance of project time management to project success, upper management may not place proper emphasis on schedule performance in comparison to cost performance. Or, if the importance of project time management is indeed understood, time management may still be overshadowed by a preoccupation with project cost management. Goldratt (1997) explained, from a management philosophy, that the "cost world" [4] and the "throughput world" [5] are in conflict, and that management cannot manage well to both "worlds" (p. 97). The diagram provided by Goldratt (1997) to depict this conflict is shown below in Figure 2-2.

---

[4] Managing to a "cost world" is a management philosophy where cost control is of primary concern and with enough local improvements everywhere, global improvement in the organization can be achieved (Goldratt, 1997, p. 88).

[5] Throughput is a measure of productivity in terms of the output of a system. Managing to a "throughput world" is a management philosophy that focuses on the weakest link for local improvements to achieve global improvement in the organization. In the "throughput world" one understands that not all local improvements will contribute to global improvement in the organization.

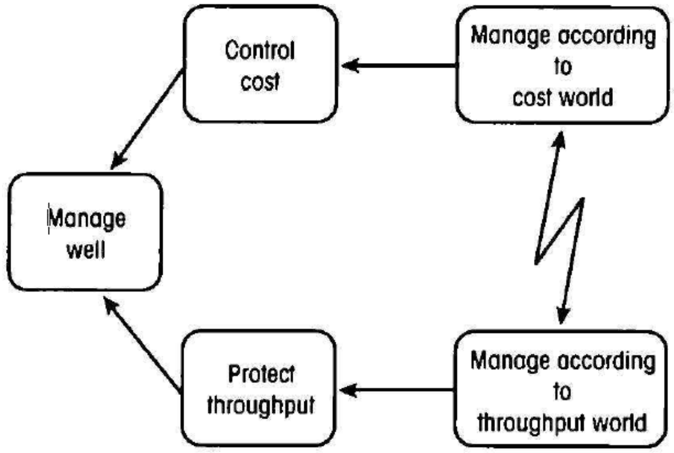

Figure 2-2. Goldratt (1997) provided a diagram about the conflict between managing to the cost world versus the throughput world (p. 97).

Management's focus on cost (making local improvements everywhere for global improvement) can overshadow the desire to direct attention toward throughput increases using CCPM (focusing on improving the weakest link to achieve global improvement) (Goldratt, 1997, p. 97). This preference toward cost control over throughput increases can be further exacerbated by the economic environment, as cost management in poor economic conditions becomes the top priority for organizations (Higgins, 2003). Higgins (2003) reported the following:

> Since CCPM is primarily a technique to help organizations shorten development time, interest in the method quickly evaporated when corporate emphasis suddenly shifted from decreasing time to market to cutting costs. Not only did the marketplace stop spending so much on consulting and on implementing new concepts, it completely lost interest in a method that was principally about saving time, not dollars. (p. 9)

Additionally, implementing new concepts requires investments of time, money, and learning which may not be justified for reductions in project schedule durations (Lynch, 2003, p. 2). Rizzo (1999b) noted that CCPM can take "six months to a year" to implement effectively (p. 33), which can deter potential implementers of the methodology. There are significant costs to consider for the new software and the needed training that managers do not want to incur (Raz, Barnes, & Dvir, 2003; Cohen, Mandelbaum, and Shtub, 2004; Oren, 2009). Learning takes into account the time needed, the costs incurred for the training, and the effects that organizational change can have on workers. The investments associated with time, money, and learning need to be justified before an organization can decide to pursue CCPM implementation. Additionally, project managers that want to implement the CCPM methodology may not have organizational support, even on a single-project basis. Without organizational support[F], as Besner and Hobbs (2008) suggested, some project management methods will not be successfully implemented or widely used (p. 21).

Goldratt (1997) discussed financial incentives for decreasing the duration of projects, including justification for CCPM based upon speed-to-market relationships between sales dollars and the lifetime of a product (p. 5). Goldratt (1997) described the curve outlining the lifetime of a product: "First sales are picking up as the product is introduced into the market, then they stabilize—it becomes a mature product, and finally it fades out" (p. 4). The diagram depicting this relationship is shown below in Figure 2-3 (Goldratt, 1997, p. 4). Organizations can capitalize on speeding up product introduction by capturing more market share or by increasing time on the market due to the limited timeframe set by patents (very important for pharmaceutical products) (Goldratt, 1997). The argument for speed-to-market[G] to improve revenue generation by introducing products faster at the beginning of the product lifecycle is likely only appealing to industries completing product development projects. This continues the discussion above that the application of CCPM may be very industry-specific. Along with speed-to-market being industry-specific, Goldratt (1997) offered a limited amount of financial benefits, such as the ability to charge premiums[H] for completing work faster (as in the construction industry described above) or to avoid fees for completing projects late (Goldratt, 1997).

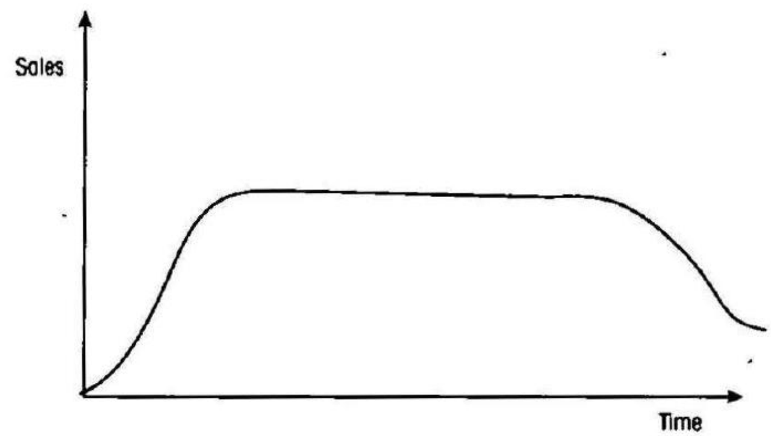

Figure 2-3. Goldratt (1997) showed the lifetime sales of a product in relation to time (p. 4).

CCPM is based upon the Theory of Constraints (TOC), which was marketed to manufacturing environments for increased throughput and decreased work-in-process[6] (WIP)/inventory. The changes in these measurements in a manufacturing process can be easily translated into financial value. Translating the TOC methodology to the project environment as CCPM requires project organizations to be more creative in determining how increased project throughput[I] or decreased WIP/inventory[J] for project resources can affect an organization's bottom line. Consider the statement by Higgins (2003): "Critical chain project management's philosophy was never about cutting costs" (p. 9). The philosophy, instead, is about completing projects faster[K] and focusing on throughput (Goldratt, 1997). On a single-project basis, there will be no cost benefits of increased throughput because throughput is a system measurement that does not hold much meaning in a single-project context. In a multi-project environment,

[6] WIP/inventory "applied to project management,…means reducing the size of the scheduled activities" such as reducing "work assignments to no more than 200-300 hrs." (Lechler et al., 2005b, p. 50), and also reducing the number of projects being worked on at the same time in a multi-project system.

increasing throughput means completing more projects in the same amount of time. The ability to realize financial benefits from increasing throughput will then depend on the project organization's ability to capitalize on freeing up resources by completing projects faster. WIP/inventory may not have much meaning for projects in relation to cost benefits for a single-project or multi-project environment, since the focus when reducing WIP/inventory is on how tasks get scheduled instead of the cost associated with each task. Therefore, WIP/inventory and throughput may, as discussed above, not be applicable to all project environments that are implementing CCPM.

Since increases to throughput are not applicable to single-projects, other measurements need to be available to measure CCPM implementation success. One method for single-project applications compares the actual completion dates using CCPM and originally-scheduled completion dates. For instance, Leach (1999a) stated that "all projects that have diligently applied CCPM have completed the project substantially under the original time estimate, fulfilled the original scope, and came in near or under the estimated budget" (p. 51). Measurements can be translated into multi-project environments in the form of reduced project schedules and increased on-time completion[L] percentages in comparison to pre-implementation levels.

In addition to the "time" component referenced in Leach's (1999) statement above, the terms "scope" and "budget" are also included as comparative measurements for CCPM implementation success, while still other comparative measurements may be possible. Leach (2005) provided a list of undesired effects present in a project organization before the implementation of CCPM (p. 62). Table 2-2 shows that CCPM seeks to solve these undesired effects, resulting in the corresponding desired effects (p. 79). Some of the improvements expected from CCPM, as shown in Table 2-2 below, can be quantitatively measured and compared (due date performance and average project duration), while others cannot (internal fighting over resources). Additionally, some of the undesired effects may not be present in an organization adopting CCPM. Therefore, each organization will need to uniquely assess their pre-implementation circumstances and uniquely define what a successful CCPM implementation means. CCPM, in addition to what is listed below in Table 2-2, can also result in quality improvements[M] as a desired effect (Lechler et al., 2005a; Robinson & Richards, 2009).

Table 2-2
Pre-implementation undesired effects resolved through CCPM implementation, resulting in the corresponding post-implementation desired effects

Pre-Implementation Undesired Effects	Post-Implementation Desired Effects
Projects frequently overrun schedule.	Projects always complete on or before the scheduled completion date.
Projects frequently overrun budget[N].	Projects complete at or under budget.
Projects frequently have to compromise on scope[O] to deliver on-time and [within] budget.	Projects always deliver the full scope.
Projects have too many changes.	Projects have few changes.
In a multi-project company, projects frequently fight over resources[P].	Projects receive needed resources without internal fights.
Project durations get longer and longer.	Project durations get shorter and shorter.
Many projects are cancelled before they complete[Q].	All projects complete.
Project work creates high stress for many participants[R].	Project work creates win-win solutions for all stakeholders.

Note. Leach (2005) provided the possible undesired effects present in the pre-implementation-of-CCPM project environment (p. 62) and the desired effects in the CCPM project environment after the completion of the implementation (p. 79).

A main advantage achieved through the implementation of CCPM is the ability to eliminate or drastically reduce the need for resources to multitask. Organizations that understand that CCPM is a solution to eliminating multitasking may establish this as a goal for the implementation[S]. CCPM also provides a process to prioritize projects and/or project tasks and bring visibility about priorities to the project teams. Organizations that see potential in improving prioritization[T] of projects and/or project tasks may establish this as part of the goals when implementing CCPM. These two goals, like some of the goals discussed above, may not be easily measured from a baseline pre-implementation condition to a comparative at-end measurement for the CCPM implementation.

Overall, there is limited information pertaining to equivalent measurements of success that can be compared across different organizations in terms of CCPM implementations. The measurements discussed above (such as reductions in completion times, improvements in on-time performance, and increases in throughput) will each have varying significance for each CCPM-implementing organization. One reason, as pointed out by Simpson and Lynch (1999) is that each organization's baseline condition is different (p. 2). Simpson and Lynch (1999) stated the following:

> The changes required to implement CCPM differ from one organization to another. What is needed in order to implement CCPM depends entirely on the starting point—the existing people, practices, policies, and mindsets that make up the organization….In most organizations, managing according to…[CCPM] characteristics would represent a significant change in how they do business. (p. 2)

Organizations need to set their own goals, in terms of an assessment of the current situation and what is needed/desired, and then define what success means to them in terms of the CCPM implementation (Simpson & Lynch, 1999, p. 3). Lechler et al. (2005a) noted that a clear definition of goals and objectives[U] is a critical success factor for CCPM implementations (Slide 26). Simpson and Lynch (1999) reported that one group failed at a CCPM implementation "because the implementation goal of achieving shorter projects was not what the organization needed" (p. 3). Determining the starting point of an organization in terms of project focus for cost, time, scope, and quality will be an important factor for CCPM implementation success. Success, in terms of the CCPM implementation, can then be measured relative to meeting the expected goals[V] in comparison to the baseline conditions. This measurement of success could then be used for comparisons across all types of CCPM implementations.

The measurements that are chosen to determine CCPM implementation success can also have an impact on the organizational buy-in for CCPM. Ram Charan, author of *Execution: The Discipline of Getting Things Done*, suggested that implementation goals be tied to "one or more" of the numbers that chief operating officers pay attention to—"revenues, margins, cash velocity, cash balance, and market share" (as cited by Realization, 2010). Realization (2007) recommended that organizations should only attempt CCPM implementation "if improving project performance will also improve the organization's bottom line[W]" and not "because it makes sense and everybody is doing it[X]" (Section 1). The primary goals that can be established in pursuit of CCPM implementation therefore include a desire to try CCPM (Realization, 2007), a desire to increase the speed at which projects are completed (Goldratt, 1997; Leach 2005; Realization, 2004; 2006), a desire to create a better working environment for employees (Leach, 2005), and a desire to directly affect the bottom line financially (Realization, 2007; 2010). The differing types of goals[Y] established in pursuit of CCPM implementation may be a factor in the implementation success rate.

One of the major hurdles for CCPM implementations, related to establishing goals, is gaining buy-in from prospective adopters of CCPM (Besner & Hobbs, 2008; Casey, 2005; Gardner, 2009; Kotter, 1995; 2002; Leach, 2005; Michalski, Miller, & Levin-Epstein, 2000; Realization, 2010). In an interview with Eugene Kania, an experienced consultant in implementation of CCPM, establishing buy-in[Z] was noted as the most significant factor for implementation (Michalski, Miller, & Levin-Epstein, 2000, Making it Work section, para. 2). Kania stated the following:

> The TOC paradigm does require a shift in focus, but companies are usually willing to make the change once they understand the significant benefits to the business and the company by using this approach….In general, the hardest part of switching to a TOC management style is establishing buy-in…. [This] can take anywhere from months to years (as cited by Michalski et al., 2000, Making it Work section, paras. 1, 2)

In a study of multiple CCPM implementations in the Defense Acquisition System and F/A-22 Program, Casey (2005) found that establishing buy-in was significant and lack of buy-in contributed to the failure of one of the implementations. Specifically, Casey (2005) identified the following related to establishing buy-in: "internal perception of a problem" needs to be present, in-depth discussion about CCPM as a solution to the problem needs to occur (p. 270), the implementation of CCPM cannot be forced (p. 271), and continuous review of CCPM concepts and progress during implementation is important (p. 272).

Kotter (2002) addressed the issue of buy-in in terms of the size of the company and the need for one percent of the company to understand how to implement methodologies that represent cultural changes. Kotter (2002) suggested that smaller companies are "faster and more agile" and are better able to implement changes such as the changes required for CCPM implementation (p. 183). Therefore, the size of the company[AA] implementing CCPM can potentially be a significant implementation success factor.

Third Possibility: Significance of Implementation Challenges

A third possible reason that CCPM is not widely used is that project practitioners are knowledgeable of CCPM, have investigated implementation of CCPM or initiated implementation efforts, are discouraged by the challenges of implementing CCPM, and are no longer pursuing the effort. Oren (2009) noted that behavioral changes are needed for CCPM to be successful and the effort to change behavior is in conflict with the tendency for people to behave in a manner that requires the least amount of effort as possible (p. 179). Dan Heath elaborated on why change is hard in an organization:

> When you share a new direction with your team, the people in the room may appreciate your logic for change. They may agree with you intellectually. And yet there is a more emotional side of them that has grown comfortable with the old way of doing things. They've been practicing routine A for years. They are very good at routine A. Now, you're trying to get them to change to routine B. Even if they agree that B is better than A, that doesn't mean it's going to be easy the next day. (as cited by Brosnan, 2011, para. 5)

Gardner (2009) reported that the presence of resistance by employees was an influencing factor in 82% of the companies that responded about reasons for failure (p. PM.03.3). Gardner went on to state that "change projects fail because of organizational resistance almost twice as often as because of any technical issues" (p. PM.03.3). Resistance to change by employees[BB] will be a factor to consider for CCPM implementation success rates.

Peterson et al. (2002) specifically addressed the behavioral changes that make implementing advanced project management concepts such as CCPM difficult. The following eight "change leadership strategies" were identified by Peterson et al. (2002): leadership, communication, relationship management, business/technology, team structure, education/training, measurement, and performance management. Many of these same change leadership strategies have been addressed in CCPM-specific articles relaying the challenges of implementing CCPM and articles related specifically to change management. This information is integrated into the discussion of the eight change leadership strategies as suggested by Peterson et al. (2002) below. Additionally, four categories—sense of urgency, vision, customization, and planning—are added to describe change strategies that were addressed in other literature but did not fit into the eight categories provided by Peterson et al. (2002).

1. Sense of Urgency. Kotter (1995, 2002) contended that the single most important factor contributing to implementing change in an organization is to create a sense of urgency[CC] for the change. This continues the discussion above about establishing buy-in: people must ultimately believe the change is needed (Gardner, 2009; Kotter, 1995; 2002).
2. Leadership. Simpson and Lynch (1999) noted that “implementing the CCPM approach is change, and implementing change requires leadership” (p. 3). More specifically, change leadership strategies include behaviors from senior management such as “packaging the change event into palatable, impact packages,” providing the necessary resources, “holding people accountable for results characteristic of changed behaviors,” and demonstrating changed behavior by example (Peterson et al., 2002, p. 2). Simpson and Lynch (1999) further stated that “leadership takes responsibility for change,” “leadership participates in the change process[DD],” and “leadership changes how they make decisions” (p. 3). Implementation participants recognize the importance and impact of leadership support and sponsorship[EE] as a contributing factor in a successful CCPM implementation (Gardner, 2009; Kotter, 1995; 2002; Leach, 2005; Lechler et al., 2005a; Simpson & Lynch, 1999; Michalski et al., 2000; Hagemann, 2001; Gupta, 2010; 2011; Realization, 2004; 2005; 2008; 2009). Hagemann (2001) stated, “Without… [the] champion’s high level of commitment and daily involvement, we would have failed to make the necessary

changes, and CCPM would have been perceived by the… [project] personnel as another 'management flavor of the month'" (p. 4.B.1-3). Casey (2005) discovered that anti-champions, leaders that openly oppose the CCPM implementation, can be significant in determining the implementation failure. Therefore, addressing the issue of anti-champions[FF] may be an important factor for implementation success (p. 289).

3. Vision. Leaders are responsible for creating a vision and communicating that vision throughout the organization (Gardner, 2009; Kotter 1995; 2002; Leach, 2005). However, vision[GG] deserves is own category according to Kotter (1995) because even if leaders are established, "without a sensible vision, a transformation effort can easily dissolve into a list of confusing and incompatible projects that can take the organization in the wrong direction or nowhere at all" (p. 63).

4. Communication. Communication with all affected stakeholders from the beginning and throughout[HH] the change is important (Gardner, 2009; Kotter, 1995; 2002; Peterson et al., 2002). The focus of the communication effort should be to highlight what is changing, why it is changing, and how CCPM "will make the job easier for those most impacted by [CCPM]" (Peterson et al., 2002, p. 2). Communication comes from the champion of the effort as well as the change agents (Casey, 2005). Change agents[II] are integral in the daily process for CCPM implementation, as identified by Casey (2005), and are the "communication link, facilitating the flow of information" about the change (p. 55). As discussed above, this process is similar to gaining organizational buy-in with the focus now being to get and maintain[JJ] the buy-in of the CCPM stakeholders (Peterson et al., 2002, p. 2). People may naturally fall into the change agent role, and one of the responsibilities of the champion (as described in the leadership section above) is "to find,

encourage and mentor these change agents to enhance chances for CCPM success" (Casey, 2005, p. 288).

5. Relationship Management. Building relationships with peripheral stakeholders[KK] (such as customers or suppliers) and managing these stakeholders' expectations can affect CCPM implementation success (Peterson et al., 2002; Simpson & Lynch, 1999). Stakeholders become concerned if there is a perception that the CCPM implementation will "impose cost to them" (Peterson et al., 2002). Therefore, involving these stakeholders in training events and gaining buy-in is important (Peterson et al., 2002, p. 2). Additionally, Simpson and Lynch (1999) noted that failure to plan for influencing how work gets done by external contractors/subcontractors can impact implementation success (p. 4). Lechler et al. (2005a) reported that the "suppliers' and internal customers' understanding of the rationale of the critical chain methodology and the resulting cooperation" was a key lesson learned in reviewing a case study of a failed implementation (Slide 26).
6. Business/Technology. The list of possible critical software solutions to use in CCPM implementations includes the following: Agile-CC, Aurora-CCPM, BeingManagement2, cc-Pulse/cc-MPulse, CCPM+, Concerto, Exepron, Lynx, ProChain, and PSNext (Vinson, 2011). Peterson et al. (2002) noted that integration of the software solution into legacy systems[LL] is important, in addition to selecting the right tool that will provide needed functionality[MM] (p. 3). Peterson et al. (2002) contended that this is "one of the crucial factors to success" and that the integration for data collection needs to be automated (p. 3). The existing culture is also a consideration when changing to tracking systems required in CCPM. Peterson et al. (2002) stated, "The collection of time and cost

data…and verifying its correctness…is a killer, particularly if time [or cost] tracking is not part of the current culture[NN]" (p. 3).

7. Team Structure. Additional roles or changes in responsibilities[OO] may be required to support and ensure CCPM implementation success (Peterson et al., 2002, p. 3). This includes integration of other stakeholders into the team structure, such as customers and external suppliers/contractors as required (Gardner, 2009; Kotter, 1995; 2002; Leach, 2005; Peterson et al., 2002). This might include the use of CCPM implementation consultants/experts[PP]; sometimes this service comes with the purchased software system (Leach, personal communication, January 17, 2012). Brandt (2003) described a successful CCPM implementation that created a project management office (PMO) to implement the CCPM methodology (p. 20). Creating a new PMO before implementation or already having a PMO[QQ] in place may be an important factor affecting CCPM implementation success. However the team structure is changed, it must possess the necessary knowledge to implement CCPM methodology. Additionally, each person's role needs to be clearly defined. Lechler et al. (2005a) identified "'knowledge centers' in the organization," "professional IT support," and "clear role definition" as critical success factors for CCPM implementation (Slide 26).
8. Education/Training. Companies can negatively affect the success of CCPM implementation by trying to save money/time by not providing effective training[RR] for all CCPM stakeholders, including senior leadership, project managers, and team members (Peterson et al., 2002, pp. 3-4). Peterson et al. (2002) noted the importance of timing the training to come after the design of the CCPM implementation system is already established (p. 3). Trainees will gain more value through practical knowledge[SS] by

learning the concepts in correlation with how the organization will actually use CCPM (Peterson et al., 2002, pp. 3, 4). Peterson et al. (2002) suggested that training that adds value in terms of affecting implementation success will review the basic concepts[TT] (such as work breakdown structure) and show "where the basic knowledge provides crucial support" to the new CCPM application (p. 4). Casey (2005), in a separate study, found that providing early training on the CCPM software[UU] can add value to achieving successful implementations by accelerating "schedule development and independence of the implementing team from external help" (p. 274).

9. Measurement. Peterson et al. (2002) stated, "Perhaps one of the greatest mistakes made with respect to any change initiative is failure to establish substantive measures through which the organization can substantiate realization of the desired state, both incrementally[VV] and 'at-end'[WW]" (p. 4). Incrementally, measuring success helps drive the implementation team forward. Casey (2005) concluded that starting with smaller projects during CCPM implementation will "greatly assist in establishment of useful templates, the proper level of detail, and generation of quick successes" (p. 273). VanOverloop and Peterson (2009) described how CCPM was first implemented at Boeing in St. Louis as a single-project solution in Support Engineering and later expanded to the large-scale Automatic Test Equipment (ATE) multi-project environment. Kotter (1995; 2002) agreed that failing to create "short-term wins" can lead to unsuccessful implementations. However, Realization (2010) warned that piecemeal fixes in order to achieve quick victories should be avoided over a full implementation[XX] from the start and stated, "Piecemeal fixes prolong implementations and compromise results" (para. 1). One reason for the differing opinions might be that the implementation effort for CCPM may be short

enough in its entirety to not require the implementation to be designed for "quick wins[YY]." Kotter (1995) noted that people like to "see compelling evidence within 12 to 24 months" (p. 65), whereas CCPM implementations may take from "six months to a year" (Rizzo, 1999b, p. 33). For 'at-end' measurements, initial goals need to be aggressive to achieve aggressive results (Realization, 2004; 2005; 2007; 2008; 2009). Realization (2004) noted that modest targets were rewarded with modest results and a lack of targets was accompanied by absence of results (Section 1). This is in agreement with "metrics equals behavior" and "you get what you measure" (Peterson et al., 2002, p. 5). While there are conflicting views in staggering implementation projects versus full implementation from the start, measurement of results is an important factor for CCPM success.

10. Performance Management. Peterson et al. (2002) stressed that even when addressing some of the issues above, CCPM implementation can "still fail…IF consideration is not given to performance management[ZZ]" in the form of consequences that characterize the design of the CCPM changes (p. 5). Much of this responsibility falls to senior leadership involvement in the form of buffer management (Realization, 2004; 2005; 2007; 2008; 2009; 2010; Simpson & Lynch, 1999). Realization (2009) stated, "Culture and behaviors stem from how you manage. Change the management rules and associated policies and measurements, and the culture and behaviors will also begin to change!" (Culture and Behaviors section). Simpson and Lynch (1999) also noted that mechanisms need to be in place to help people focus on critical chain tasks, such as one organization attaching "a red chain to the door or cubicle of anyone working the critical chain" (p. 3). Simpson and Lynch (1999) stated the following:

> Change the information used to make decisions…[such as] buffer reporting as the basis for weekly staff meetings…[and] decisions on resource allocation and priority setting…dependent on the status of project buffers. This may indeed be the ultimate indicator of the degree of leadership commitment—are the measurements changed to align the organization with CCPM? (p. 3)

Kotter (1995) noted that incorporating the performance measurements around the change helps to institutionalize the change so it can survive management turnover (p. 67).

11. Customization. Casey (2005) found that when comparing different CCPM implementations in the Defense Acquisition System and F/A-22 Program, 'cookie-cutter'/one-size-fits-all implementations were less successful than implementations that tailored the CCPM methodology to their specific environment[AAA] (p. 273). This can be attributed to implementation participants taking ownership and responsibility for CCPM success (Casey, 2005, p. 296). Casey (2005) also found that customization does not mean compromising on the essential concepts of CCPM and that compromises in the CCPM methodology that are not fixed can cause failure (p. 297).
12. Planning. The implementation of CCPM needs to be planned like a project[BBB] (Leach, 2005; Peterson et al., 2002). Simpson and Lynch (1999) highlighted that organizations that fail to look past the "first few tasks required" cannot expect to be successful in CCPM implementation (p. 3). Additionally, Simpson and Lynch (1999) observed that when planning focuses on "achieving only a handful of small but highly-leveraged changes," CCPM implementation can be very successful (p. 3).

While the above factors are directly related to the CCPM implementation in terms of change management, some potential implementers of CCPM may also be discouraged by the perception of complexity[CCC] of CCPM concepts and decide not to pursue the implementation effort (Lechler et al., 2005a). For instance, organizations that are unfamiliar with network-based scheduling will have a steeper learning curve to implement CCPM than organizations that are already familiar with these scheduling techniques[DDD] (Simpson and Lynch, 1999, p. 2). Oren (2009) noted that an organization may start with managers that are ignorant "on the use of any of the listed techniques in developing, monitoring and controlling project schedules…where schedules are generally listed as Gantt charts, often without a critical path or any degree of graphical progress reporting" (p. 179). Lechler et al. (2005b) reported that "a number of firms failed to implement CC[PM] and complained about the complexity of the CC[PM] approach in changing behaviors and expectations and managing the extra complexity of buffer management" (p. 56). The starting point of an organization in terms of scheduling competencies, such as use of the critical path method[EEE], may be a significant factor in the success of CCPM implementations. Complexities in terms of specific concepts and how each might affect the implementation effort are described in a subsequent section.

Fourth Possibility: An Unnecessary Solution for Critical Path Method

A fourth and final possibility as to why CCPM is not widely used is that project practitioners are aware of CCPM but do not believe that CCPM has anything new to offer over traditional CPM. Some authors discuss the concepts behind CCPM, but say the challenges are nothing that CPM cannot solve (Duncan, 1999; Wilkens, 2000; Filatraut & Peterson, 2000; Uyttewaal, 1999). There are also claims that some of the CCPM concepts are not new knowledge and instead are repackaging of old ideas (Duncan, 1999; Triestch, 2005). For instance, Weist (1964) introduced the 'critical sequence' (comparable to critical chain in terms of sequencing tasks) to address CPM's weaknesses in terms of resource-constrained scheduling. Triestch

(2005) provided further discussion about how each critical chain concept has been separately introduced previously in literature before the introduction of CCPM.

CCPM is, however, a combination of technical scheduling concepts previously introduced, along with behavior changes in how work is conducted, to provide a holistic schedule planning, monitoring, and controlling solution (Cervany & Galup, 2002). Casey (2005) supported CCPM as both an innovation that puts together previously unrelated concepts, and an organizational innovation that changes individuals' behavior to improve organizational performance (pp. 39, 40). PMBOK® (2008) has also recognized critical chain as a separate scheduling method compared to critical path (Project Management Institute, 2008). Even though critical chain is now recognized in the project management community, further criticisms need to be addressed in terms of how they might inhibit successful implementation of CCPM, in order to determine if there are underlying faults of the CCPM process that contribute to failure of CCPM implementations. One factor might be directly related to the lack of a project management standard for CCPM[FFF]. This was cited as a problem related to failed CCPM implementations according to Lechler et al. (2005a) (Slide 36). Specific CCPM concepts that might create problems or be contributing factors toward the success of CCPM implementation are discussed further below.

Understanding the Potential Weaknesses of CCPM

CCPM is presented as a holistic solution, but there is value in analyzing specific technical concepts within the solution to determine weaknesses and potential improvements. Looking at the weaknesses from a theoretical perspective can provide insight into potential problems that might impede the implementation of CCPM. Some specific critical chain concepts that have been critically evaluated include the following: task duration estimation, buffer sizing, determination of baseline critical chain schedule, re-scheduling, buffer management, elimination of multitasking, coordination with external suppliers, complexity of the CCPM process, and integration of CCPM with Earned Value Management (EVM). Finally, discussion is included about which features of CCPM are necessary for positive implementation results.

One of the first steps in determining the critical chain is obtaining task duration estimates. Goldratt's (1997) suggested method determined task duration estimates by arbitrarily cutting the given estimates in half to gain the 50% probability of completion estimates. This method has faced criticism by other authors (Herroelen & Leus, 2001; Piney, 2000; Raz et al., 2003; Shou & Yeo, 2000). Shou & Yeo (2000) elaborated their concerns about determining task duration estimates[GGG] without considering the "relative uncertainties of different activities[/tasks]" or "management's attitude towards risk" (p. 165) and proposed alternative methods for task duration estimation. The simplest solution proposed by Shou & Yeo (2000) was to train the team members how to directly estimate average task duration (p. 165). Although people were asked to estimate average (mean) duration (which, according to Herroelen and Leus (2001), can provide the safest estimates for duration), Shou and Yeo (2000) reported that people usually provided median estimates instead and that this difference will not be significant for CCPM purposes (p. 165). Lechler, et al. (2005b) proposed further research to answer the following unresolved questions about task estimation: "Is it reasonable to ask that activity durations be estimated with no included safety margin? Can this practice be sustained?" (p. 57).

Project buffer sizing in CCPM, similar to task duration estimates, is sized to 50% of the total project's duration that was removed from duration estimates, according to Goldratt (1997), and is commonly referred to as the "cut and paste" method (Yang, Fu, Huang, & Tao, 2008). This method for buffer sizing[HHH] has also been criticized as being arbitrary (Herroelen & Leus, 2001; Piney, 2000; Raz et al., 2003; Shou & Yeo, 2000). Other buffer sizing techniques have been recommended, including the following: lognormal distributions (Newbold, 1998), root square error (Leach, 2000; 2005), Monte Carlo simulation techniques (Hoel & Taylor, 1999; Tenera, 2008; Tenera & Machado, 2007); fuzzy techniques (Duc Long & Ohsato, 2008; Li & Chen, 2007; Shi & Gong, 2009; Zhang, Cui, & Bie, 2011; Zhao, You, & Lv, 2008), heuristic algorithms (Liu, Ren, & Xie, 2008, Zhao, You, & Zuo, 2010), problem characteristics (Tukel, Rom, & Eksioglu, 2006), and queuing theory (Yang & Gao, 2011). The cut and paste method advocated by Goldratt (1997) gives the longest buffer durations in comparison to the other methods suggested above. This is in agreement with a criticism by Herroelen and Leus (2001) that the calculation using the suggested cut and paste method results in buffers that are too long (p. 564).

While both estimation and buffer calculation as introduced by Goldratt (1997) may be arbitrary, the best practice in terms of real-world application, or benchmark, has not been publicized. However, Simpson (2010) proposed an alternate solution based upon personal experience for problems associated with both task duration estimation and buffer sizing for CCPM:

> Two task duration estimates are specified for each task—a 50 percent probable and a 90 percent probable estimate….Being allowed to estimate a range of possible task durations provides team members with a mechanism to account for the uncertainty in the project environment and reduces the team’s anxiety level associated with the process. The two estimates are used to calculate the project buffer that shows the range of possible completion dates for the project….Experience shows that this greatly reduces the

> potential for conflict between the team and leadership, maintains the integrity of the estimating process, and improves the credibility (believability) of the schedules. (p. 33)

As discussed in the above excerpt, there may be behavioral implications such as anxiety and conflict[III] that are rooted in these specific critical chain concepts—task duration estimation and buffer sizing. Therefore, task duration estimation methods and buffer sizing techniques should be included as potential critical chain implementation factors.

Another criticism in the literature about critical chain concepts is the determination of the baseline critical chain schedule. Once sequenced tasks have been resource-leveled, the critical chain may not be obvious since there may be multiple critical chains of the same total duration; the critical chain will have to be arbitrarily picked (Herroelen & Leus, 2001; Herroelen et al., 2002). A given software package used to choose the critical chain in comparison to another software package may determine an entirely different critical chain path and a non-minimal baseline schedule (Herroelen & Leus, 2001; Herroelen et al., 2002; Lechler et al., 2005b).

This issue of determining the baseline CCPM schedule is further complicated after the feeding buffers are inserted following the non-critical tasks. The addition of feeding buffers may create additional resource conflicts, and, once the schedule is again resource-leveled with the inserted feeding buffers, gaps may need to be inserted into the critical chain (Herroelen & Leus, 2001; Herroelen et al., 2002). For instance, analyzing Figure 2-4 below, there is a gap that was introduced in the critical chain, between “T3” and “T4,” after the feeding buffers were added.

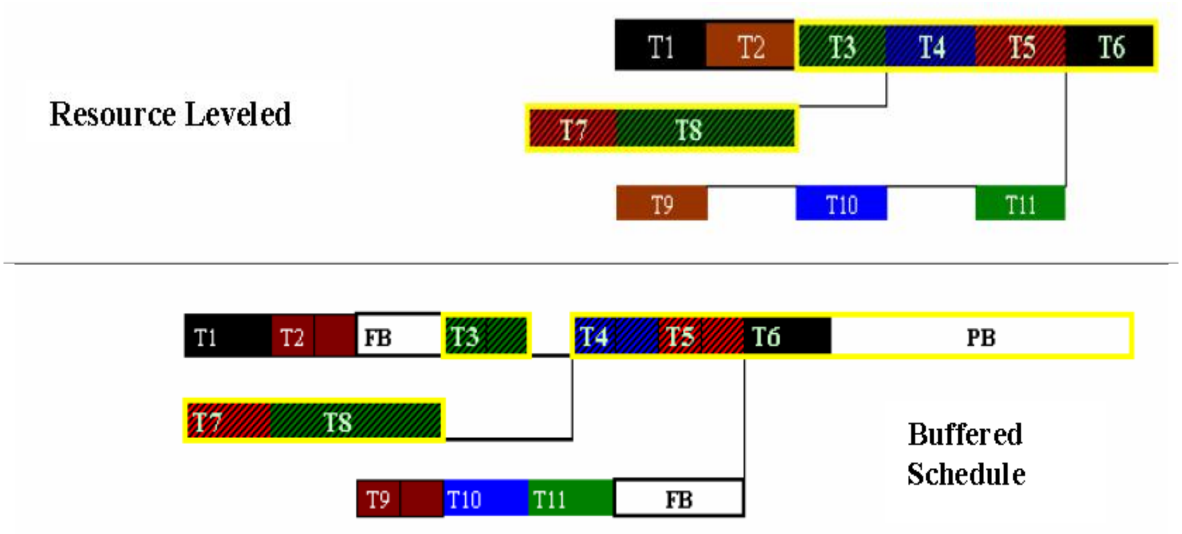

Figure 2-4. Robinson and Richards (2009) displayed how to convert a resource-leveled CCPM schedule into a buffered CCPM schedule (PS.S03.8). *Note that each color represents a different resource and that the shaded colors represent where the task for that resource is on the critical chain.*

Herroelen and Leus (2001); Herroelen et al. (2002); and Cui, Tian, and Bie (2010) suggested rescheduling the CCPM schedule once the feeding buffers are added to determine a critical chain that does not include gaps. Researchers such as Suwa, Morita, and Sandoh (2010) and Chen and Sun (2010) offer other solutions, such as inserting dummy values for buffers or using a formula to determine if rescheduling is needed after the insertion of feeding buffers. A discussion with Larry Leach concerning this issue revealed that when implementing critical chain concepts, getting overly frustrated with gaps in the critical chain may be an indication of other symptoms that inhibit implementation of the critical chain concepts—thinking deterministically about the sequenced tasks when the tasks themselves will have variable completion times (personal communication, January 17, 2012). Whether or not the implementing organization reschedules to determine the baseline critical chain schedule, the complexities of determining a baseline schedule[JJJ] should be included as a critical chain implementation factor.

Alternately, a modified version of CCPM (CC-Lite) that removes the feeding buffers altogether and returns the non-critical paths feeding the critical chain to early-start instead of late-start has been suggested (Lechler et al., 2005b, p. 56). One of the reasons for failure in a case study by Lechler et al. (2005a) was that there were “too many buffers” that resulted in the CCPM system being “too complex[KKK] to manage” (Slide 34). Other buffers were discussed in reference to a simplified version of CCPM (CC-Lite) that uses only three buffers. The following conclusions were drawn by Lechler et al. (2005a): milestone buffers are always needed, project buffers are always needed, and drum buffers are occasionally needed (Slide 41). Drum buffers are only occasionally needed because Lechler et al. (2005a) found that some multi-project organizations do not have a company-wide drum resource (Slide 21). The lack of need for resource, feeding, and capacity buffers as success factors for CCPM implementation is not fully substantiated and requires further validation. The influence of each of the buffers needs to be investigated in relation to the success rates of CCPM implementations (See Appendix B for a description of each of the buffers).

Once the CCPM schedule is established, the critical chain remains unchanged through the project, barring extenuating circumstances (Goldratt, 1997). By limiting changes in the critical chain, the organization may be missing opportunities to reschedule and achieve faster completion times (Herroelen & Leus, 2001; Herroelen, Leus, & Demeulemeester, 2002). During the course of the project, because the critical chain does not change, project resources may be incorrectly applying effort to tasks that are not technically the most critical tasks in determining shortest project completion time, and, therefore, rescheduling should be allowed (Herroelen & Leus, 2001; Herroelen et al., 2002; Herroelen & Leus, 2005). Leach (2005) noted that the prioritized task list is used in CCPM software to ensure that people are working on the highest-priority tasks

(p. 184). The prioritized list is developed to ensure that the available resources are working on the next task that is "available to start…and…causing the most project-buffer penetration" (Leach, 2005, p. 166).

Even with the use of the prioritized list, one could conclude that the CCPM method does not allow rescheduling at an adequate frequency, and that this inadequacy should be a critical chain implementation factor. Simpson and Lynch (1999) explained that rescheduling should be the exception and "accomplished only in the event of a severe project disruption" (1999). Leach further explained that rescheduling should occur in either of two conditions, either (1) when "project scope has changed to require substantive additional tasks" or (2) "when the project buffer is fully consumed and the [project] team cannot come up with methods to recover before project end" (personal communication, February 17, 2012). Alternatively, introducing frequent rescheduling (or reprioritization[LLL]) beyond what is suggested above may also be a factor to inhibit CCPM implementation success. In this case, management is responding to common-cause variation and decisions will be counterproductive and introduce system nervousness (Herroelen et al., 2002, p. 58). Common-cause variation occurs when the task durations are fluctuating within expected control limits (Leach, 2001, p. 48). This differs from special-cause variation that occurs when task duration fluctuations are outside of the expected control limits (due to special circumstances) (Leach, 2001, p. 48).

Reacting inappropriately to common-cause variation in buffer management can negatively impact project progress. Patrick (2001) stated the following:

> The thresholds are used to determine whether it is appropriate to act to mitigate the impact of these risks or accept the remaining risk as within the ability of remaining buffer to deal with it. Sometimes it can be even more important to avoid developing and

> implementing unnecessary corrective actions, especially when those actions require significant time and attention to develop. (p. 3)

For buffer management, Herroelen and Leus (2001) criticized, “buffer penetration will often lead to the immediate creation of resource conflicts somewhere in the schedule, which may prevent the buffers from acting as a true proactive mechanism” (p. 567). However, if buffer management is used properly along with the prioritized list as mentioned above, then before buffer penetration becomes an issue (buffer penetration in the red on the fever chart), actions are put into place. However, failing to use buffer management properly[MMM] has been linked to CCPM implementation failures (Casey, 2005; Realization, 2004; 2005; 2008). “The project team must plan and act to recover when necessary, as dictated by buffer status, but only when necessary, in order to avoid unnecessary distraction of project resources who should be allowed to focus on their work” (Patrick, 1999a, p. 62). Leach noted that when implementing CCPM, managers may have a hard time trusting the buffer management system and letting project resources focus on their work, unnecessarily interrupting workers[NNN] for updates and status reports (personal communication, January 17, 2012).

One of the behavioral requirements of CCPM is to limit multitasking. Pinto (2002) stated that “because CCPM argues for dedicated resources in a multi-project environment where resources are shared, it is impossible to avoid multitasking and hence, the power of CCPM is severely diminished” (p. 27). However, the purpose of CCPM is to create a working environment where resources do not need to multitask. In order to make CCPM work, management needs to ensure multitasking is discouraged. Patrick (1999a) indicated that management is responsible “for protecting resources from competing priorities that drive multitasking” (p. 62). Therefore, as discussed above, the performance management system needs to reinforce a project environment where avoidance of multitasking by project team members is possible[OOO]. Upper management must be integral in supporting this effort. Additionally, full implementation of CCPM across all projects that have shared resources will be essential in creating an environment where focused work is possible (Goldratt, as cited by Cabanis-Brewin, 1999, p. 50).

Critical chain project management in practice typically does not use milestones and requires project participants to work in a different way. However, what happens when external suppliers are introduced into the project picture? How are external suppliers integrated into CCPM? Pinto (2002) pointed out that CCPM "makes coordinated scheduling, particularly with external suppliers [such as for delivery of critical components], highly problematic" (p. 27). Raz, et al. (2003) further discussed that that the use of resource buffers to resolve issues with external resources may not be enough and that "outside contractors…may not have the flexibility to drop their ongoing jobs and invest their full attention on their assigned project task" (p. 30). There is a need for additional coordination during the procurement management process as suggested by Simpson and Lynch (1999). Simpson and Lynch (1999) emphasized the importance of including subcontractors and vendors during implementation planning because otherwise, "there may not be mechanisms in place to influence how the work [is completed]." They noted an example of a failed implementation because this issue was not addressed during implementation planning (p. 4). Additionally, Leach (1999a) noted that "in risky situations, and in subcontracts, it may be appropriate to include financial incentives in the resource buffers, such as paying for early delivery, penalties for late delivery, or paying for standby time" (p. 46). Coordination with external suppliers[PPP] should be included as a CCPM implementation factor.

There are special factors that have been introduced in the literature that may contribute to the success or failure of CCPM implementations. One of the issues is related to the late-start orientation[QQQ] of all the tasks on a CCPM schedule that do not fall on the critical chain. Yang (2007) stated the following about CCPM in relation to construction projects:

> Activities that do not set logical relationships correctly will be pushed to their ALAP (as late as possible) dates. This results in wrong construction procedures. Therefore, it is necessary to determine rigid logical relationships for running [CCPM] in the construction industry. (pp. 31-32)

Patrick (1999a) recognized the difficulty in accurately identifying precedence relationships and that "project managers, when building project schedules must realize resource dependency is as real as task dependency when determining what is critical for the project" (p. 62). The complexity involved in completely defining the logical relationships in a schedule may be too difficult for planners, and this complexity in planning could contribute to less successful CCPM implementations. Complexity may also be introduced by the types and quantity of tasks that are being scheduled. Huang and Yang (2009) demonstrated using a simulation that "the extent to which it [CCPM] outperforms CPM is determined by the attributes of the project" (p. 410). Project attributes include "both the number of activities[/tasks][RRR] in the critical chain and the uncertainty extent of the activity[/task] duration[SSS]" (Huang & Yang, 2009, p. 410). Therefore, capturing these types of project attributes may be important in determining CCPM implementation success.

Another special topic that has been addressed in the literature is the integration of Earned Value Management (EVM) with CCPM (Gupta, 2008; Leach, 2011; Levine, 1999; Peterson & Filiatrault, 2000; Piney, 2000; Realization, 2007). Peterson and Filiatrault (2000) differentiated EVM's use in relation to CCPM and stated that EVM "should be used to report the past achievements and CCPM should be used to manage/report on the future" (p. 730). Realization

(2007) described how mixing EVM and CCPM is not recommended and "will render them both useless" (Realization, 2007, Section 3). Leach (2011) elaborated on how the two methods complement each other in some ways (such as cost management) while not in others (schedule management). For instance, Leach (2011) noted that "the cost of tasks need not (and often does not) correlate with the schedule impact of the task" where instead "task cost is probably more proportional to scope than it is to schedule" (p. 13). In respect to the cost being associated with scope, EVM and CCPM complement each other for cost management. Alternately, EVM focuses on cost measurements for schedule management that cannot be directly related to schedule measurements, while CCPM focuses directly on schedule measurements for schedule management (Leach, 2011, p. 13). Leach noted, however, that both EVM and CCPM require solid foundations in project management (PM) fundamentals[TTT] and CCPM implementations may be more successful when combining CCPM and EVM by virtue of increases in use of organizational project management skills (Leach, personal communication, February 17, 2012). The use of EVM[UUU] in organizations needs to be assessed as a factor for CCPM implementation success.

As an extension of the previous discussion in reference to full implementation versus partial implementation, the question arises, "What are the essential features of CCPM that influence implementation success?" Realization (2005; 2006; 2008) emphasized the importance of implementing the core concepts for successful CCPM implementations. Simpson and Lynch (1999) suggested that "not all characteristics [of CCPM] will be evident in all CCPM organizations, nor are all necessary to begin realizing improvements in performance" (p. 2). Furthermore, some authors have alluded to the possibility of taking some of the concepts in CCPM and applying them to CPM (Levine, 1999; Filiatrault & Peterson, 2000, Lechler et al., 2005b). Leach (1999a) noted that "all projects that have diligently applied CCPM have completed the project substantially under the original time estimate, fulfilled the original scope, and came in near or under the estimated budget" (p. 51). Leach clarified the phrase "diligently applied CCPM" to mean that CCPM was applied to the fullest extent, i.e., reduced task durations to 50% probability of completion, inserted buffers, updated project status on a daily or weekly basis, used buffer management and stopped people from multitasking (personal communication, January 17, 2012).

Simpson and Lynch (1999) noted that the ability of the implementing organization to capture distinguishing characteristics of CCPM is an important variable to consider when evaluating the success rates of CCPM implementations (p. 2). Simpson and Lynch (1999) demonstrated this idea by outlining the key CCPM concepts that all successful organizations master in terms of project planning in accordance with CCPM, project control through buffer management, and the ability to create a "work environment that is characterized by focused effort" (p. 2). These core concepts, provided by Simpson and Lynch (1999), have been adapted to capture all of the following features of CCPM (see Appendix B for a full description of critical chain concepts):

- Clear definition of scope for project(s) [VVV]
- Average work required and resource requirements assigned for each task in schedule[WWW]
- Reduced task duration estimates at 50% probability of completion[XXX]
- Clear definition of baseline critical chain[YYY]
- Buffers (project buffers[ZZZ], feeding buffers[AAAA], resource buffers[BBBB], milestone buffers[CCCC], drum buffers[DDDD], and capacity buffers[EEEE]) (Lecher et al., 2005a, Slide 41)
- Projects in a multi-project environment deliberately staggered/ pipelined[FFFF]

- Buffer management used to monitor and control projects on at least a weekly basis[GGGG]
- Buffer management used to plan and act on recovering buffer when needed[HHHH]
- Remaining task duration used when reporting status on project tasks[IIII]
- Rescheduling of the critical chain used as the exception and not the rule[JJJJ]
- Environment created that minimizes the need for multitasking[KKKK]
- Project team members understanding task priorities (priority task list) [LLLL]
- Highest-priority tasks completed as quickly as possible and given to next resource without delay[MMMM]
- Integration of contractors/suppliers into CCPM taken into account during project planning[NNNN]

The specific features of CCPM implemented[OOOO] should be considered as a factor when addressing the success rate of CCPM implementations.

Summary

The preceding literature review consolidates the potential factors that may have an impact on the success or failure of CCPM implementations. There have been limited studies conducted, none of which can be considered comprehensive, that provide some insight into critical success factors related to the implementation of CCPM. These include studies by Simpson and Lynch (1999), Casey (2005), Lechler et al. (2005a), Realization (2004; 2005; 2006; 2007; 2008; 2009; 2010), and Peterson, Oliver and Webb (2002). This literature review, using the deductive technique, expanded upon these exploratory studies to take a comprehensive look at all factors that can potentially influence CCPM implementation success. The factors are discussed in five different groupings, including pre-existing organizational conditions, organizational goals when pursuing CCPM implementation, features of CCPM actually implemented, factors related to change management, and factors related specifically to the CCPM methodology. All of these factors are discussed individually in the endnotes of this chapter. Table 2-3 below shows a condensed list of the factors that have been derived from the literature review.

Table 2-3
Summary of factors identified in the literature review

Pre-Existing Conditions	Change Management	Critical Chain Methodology
• Industry Type • Project Management • Size of the Organization • Use of Scheduling Techniques • Project Attributes • Project Focus Implementation Goals • Try It Out • Speed Up Projects • Better Working Environment • Directly Affect Bottom Line	• Buy-In / Organizational Support • Leadership Support • Urgency • Resistance • Communication • Established Vision • Stakeholder Involvement • Software Integration / Functionality • Changes in Team Structure • Training • Measurements of Success • Performance Management Reinforcement • Customization Allowed for Buy-In • Implementation Planned as a Project	• Lack of Critical Chain Standard • Complexity of Method • Multitasking Eliminated • Frequent Reprioritization • Management Interruptions • Non-Project Work • Coordination with External Suppliers • Integration of Earned Value Management • Integration of Lean Methods Features Implemented • Full Implementation • Only Some Features Implemented

---

[A] Critical chain concepts are not widely known. Obtaining enough survey participants with both knowledge and experience using the critical chain concepts may be difficult. Screening the survey participants, using skip logic, will help pre-qualify the survey participants to move through the entire survey.
[B] Varying definitions and terminology for CCPM may cause confusion. The survey needs to provide a clear definition of CCPM for survey participants.
[C] Industry type may be a success factor related to pre-existing conditions in an organization.
[D] Non-project responsibilities of project resources may be a success factor related specifically to the CCPM methodology.
[E] Integration of Lean Methods with CCPM may be a success factor related specifically to the CCPM methodology.
[F] Organizational support (similar to organizational buy-in) for CCPM may be a success factor related specifically to the change process.
[G] Speeding up a new product introduction into the market may be a CCPM implementation goal that can influence implementation success.
[H] The ability to charge premiums for faster project completions may be a CCPM implementation goal that can influence implementation success.
[I] Increasing project throughput may be a CCPM implementation goal that can influence implementation success.
[J] Reducing the amount of work-in-process/inventory for project resources may be a CCPM implementation goal that can influence implementation success.
[K] Completing projects faster may be a CCPM implementation goal that can influence implementation success.
[L] Increasing on-time completion percentages may be a CCPM implementation goal that can influence implementation success.

[M] Increasing quality on projects may be a CCPM implementation goal that can influence implementation success.
[N] Minimizing cost increases for the project(s) may be a CCPM implementation goal that can influence implementation success.
[O] Minimizing scope change for the project(s) may be a CCPM implementation goal that can influence implementation success.
[P] Finding a better way to manage project resources may be a CCPM implementation goal that can influence implementation success.
[Q] Increasing the chance(s) that the project(s) will be completed may be a CCPM implementation goal that can influence implementation success.
[R] Reducing stress in the work environment may be a CCPM implementation goal that can influence implementation success.
[S] Minimizing the need for multitasking by project resources may be a CCPM implementation goal that can influence implementation success.
[T] Having the ability to better prioritize projects and/or project tasks may be a CCPM implementation goal that can influence implementation success.
[U] Having survey participants respond about the extent of the goals and objectives for the CCPM implementation will help determine if the project organization had clear goals and objectives before implementing CCPM.
[V] For comparative purposes between different CCPM-implementing organizations, each survey participant can determine if his/her organization is in a worse position, same position, or better position in relation to its goals after CCPM implementation.
[W] Attempting to achieve financial benefits that will affect the organization’s bottom line may be a CCPM implementation goal that can influence implementation success. Alternately, realizing financial benefits from CCPM may be a commonly-shared factor amongst successful CCPM implementations.
[X] Trying something new that other organizations are having success with may be a CCPM implementation goal that can influence implementation success.
[Y] The specific goals that CCPM implementers pursue may influence implementation success. Participants will be able to provide the types of goals related to their specific CCPM implementation experience.
[Z] Establishing buy-in for CCPM may be a success factor related specifically to the change process.
[AA] The size of the organization may be a success factor related to pre-existing conditions in an organization.
[BB] Resistance by employees to the CCPM implementation may be a success factor related specifically to the change process.
[CC] Sense of urgency created for the CCPM implementation may be a success factor related specifically to the change process.
[DD] Leadership participating throughout the CCPM implementation may be a success factor related specifically to the change process.
[EE] Having a champion from upper/senior management for the CCPM implementation may be a success factor related specifically to the change process.
[FF] Presence of anti-champions that actively oppose the CCPM implementation may be a success factor related specifically to the change process.
[GG] Having an established vision for the CCPM implementation may be a success factor related specifically to the change process.
[HH] Communication about the CCPM implementation throughout the process may be a success factor related specifically to the change process.
[II] Having change agents involved in the daily effort of implementing CCPM may be a success factor related specifically to the change process.
[JJ] Maintaining buy-in for CCPM may be a success factor related specifically to the change process.
[KK] Involvement of peripheral stakeholders such as customers/suppliers in the CCPM implementation may be a success factor related specifically to the change process.
[LL] Integration of the CCPM software into the legacy system may be a success factor related specifically to the change process.
[MM] Functionality of the CCPM software may be a success factor related specifically to the change process.
[NN] The presence of time or cost tracking as part of the organizational culture may be a success factor related to pre-existing conditions in an organization.
[OO] Changes in the team structure (roles and responsibilities) to support the CCPM implementation may be a success factor related specifically to the change process.

[PP] The presence of CCPM implementation consultants/experts may be a success factor related specifically to the change process.
[QQ] The presence of a Project Management Office (PMO) in the CCPM implementation may be a success factor related to pre-existing conditions in an organization.
[RR] Receiving adequate funding/attention for a CCPM training initiative from the organization may be a success factor related specifically to the change process.
[SS] CCPM training conducted in a practical fashion may be a success factor related specifically to the change process.
[TT] Reviewing basic project management concepts that support CCPM during training may be a success factor related specifically to the change process.
[UU] Conducting early training on the CCPM software may be a success factor related specifically to the change process.
[VV] Using incremental measurements to determine CCPM implementation success may be a success factor related specifically to the change process.
[WW] Using 'at-end' measurements at the completion of the CCPM implementation may be a success factor related specifically to the change process.
[XX] Fully implementing all the features of CCPM may be a success factor related specifically to the extent in which the CCPM features were implemented.
[YY] Designing the CCPM implementation to achieve "quick wins" may be a success factor related specifically to the change process.
[ZZ] Using performance management to reinforce CCPM behaviors (such as limiting multitasking) may be a success factor related specifically to the change process.
[AAA] Allowing customization of the implementation without compromising on the CCPM concepts to build ownership may be a success factor related specifically to the change process.
[BBB] Planning the CCPM implementation like a project may be a success factor related specifically to the change process.
[CCC] The perception of complexity of the CCPM process may be a success factor related specifically to the CCPM methodology.
[DDD] The familiarity of the organization with network-based scheduling techniques may be a success factor related to pre-existing conditions in an organization.
[EEE] Use of schedule monitoring and controlling using the critical path method may be a success factor related to pre-existing conditions in an organization.
[FFF] The desire for a CCPM standard due to the lack of such a standard may be a success factor related specifically to the CCPM methodology.
[GGG] Satisfaction with the method used for activity/task duration estimates may be a success factor related specifically to the CCPM methodology.
[HHH] Satisfaction with the method used for buffer duration calculations may be a success factor related specifically to the CCPM methodology.
[III] Conflict between leadership and the project team about task/buffer duration estimates may be a success factor related specifically to the CCPM methodology.
[JJJ] Difficulty in determining the correct baseline critical chain schedule may be a success factor related specifically to the CCPM methodology.
[KKK] The complexity of the CCPM method may be a success factor related specifically to the CCPM methodology.
[LLL] Frequent reprioritization of tasks may be a success factor related specifically to the CCPM methodology.
[MMM] Proper use of buffer management may be a success factor related specifically to the extent in which the CCPM features were implemented.
[NNN] Frequent management interruptions may be a success factor related specifically to the CCPM methodology.
[OOO] The ability for project resources to conduct focused work and eliminate multitasking may be a success factor related specifically to the CCPM methodology.
[PPP] Difficulty in coordinating with external suppliers may be a success factor related specifically to the CCPM methodology.
[QQQ] Problems caused by delayed starts of non-critical chain (feeding) paths may be a success factor related specifically to the CCPM methodology.
[RRR] The number of activities/tasks in the critical chain may be a success factor related to pre-existing conditions in an organization.

[SSS] The uncertainty involved in estimating project activity/task durations when developing initial project schedules may be a success factor related to pre-existing conditions in an organization.
[TTT] The use of standard project management practices for planning and execution of projects may be a success factor related to pre-existing conditions in an organization.
[UUU] The use of Earned Value Management in conjunction with CCPM may be a success factor related specifically to the CCPM methodology.
[VVV] Identifying clear scope for the project(s) may be a success factor related specifically to the extent in which the CCPM features were implemented.
[WWW] Having clear task definitions in terms of average work required and resource assignments may be a success factor related specifically to the extent in which the CCPM features were implemented.
[XXX] Using a 50% probability estimate for task duration estimates may be a success factor related specifically to the extent in which the CCPM features were implemented.
[YYY] Clearly defining the baseline CCPM schedule may be a success factor related specifically to the extent in which the CCPM features were implemented.
[ZZZ] Use of project buffer(s) may be a success factor related specifically to the extent in which the CCPM features were implemented.
[AAAA] Use of feeding buffers may be a success factor related specifically to the extent in which the CCPM features were implemented.
[BBBB] Use of resource buffers may be a success factor related specifically to the extent in which the CCPM features were implemented.
[CCCC] Use of milestone buffers may be a success factor related specifically to the extent in which the CCPM features were implemented.
[DDDD] Use of drum buffers may be a success factor related specifically to the extent in which the CCPM features were implemented.
[EEEE] Use of capacity buffers may be a success factor related specifically to the extent in which the CCPM features were implemented.
[FFFF] Deliberately staggering/pipelining projects in a multi-project environment may be a success factor related specifically to the extent in which the CCPM features were implemented.
[GGGG] Use of buffer management for monitoring and controlling on at least a weekly basis may be a success factor related specifically to the extent in which the CCPM features were implemented.
[HHHH] Using buffer management to plan and act on recovering buffer when needed may be a success factor related specifically to the extent in which the CCPM features were implemented.
[IIII] Using remaining task duration for status reporting may be a success factor related specifically to the extent in which the CCPM features were implemented.
[JJJJ] Rescheduling as an exception may be a success factor related specifically to the extent in which the CCPM features were implemented.
[KKKK] Creating an environment with minimized multitasking may be a success factor related specifically to the extent in which the CCPM features were implemented.
[LLLL] Providing project team members with task priorities may be a success factor related specifically to the extent in which the CCPM features were implemented.
[MMMM] Completing the highest priority tasks quickly and immediately passing them to the next resource (road-runner mentality) may be a success factor related specifically to the extent in which the CCPM features were implemented.
[NNNN] Integration of contractors/suppliers in the CCPM process may be a success factor related specifically to the extent in which the CCPM features were implemented.
[OOOO] The use or lack of use of specific CCPM features is a group of factors that may influence the success rate of CCPM implementations.

CHAPTER 3

OBJECTIVE

The objective of this study is to identify and statistically validate factors that influence CCPM implementation success.

The following five questions were evaluated as part of this thesis:

1. Do pre-existing conditions in an organization influence CCPM implementation success?
2. Do any goals established for the CCPM implementation influence CCPM implementation success?
3. What implemented features of CCPM influence CCPM implementation success?
4. What factors attributable to change management influence CCPM implementation success?
5. What factors attributable directly to CCPM methodology influence CCPM implementation success?

Potential CCPM implementers, using this research, will be able to understand what factors in each of the five categories listed above are influential in achieving high-success implementations over low-success implementations.

CHAPTER 4

METHODOLOGY

Two methods, a survey and an interview, were used to gather data and information for analysis.

Survey Development and Analysis

The types of question formats used in the survey determined the quality of the responses and how the responses were analyzed. Likert-type response formats are the “most widely-used method of measuring personality, social, and psychological attitudes” (Hodge & Gillespie, 2003, p. 45). A common Likert-type response format provides a positively- or negatively-worded statement to which the respondents state their level of agreement or disagreement with said statement (Hodge & Gillespie, 2003, p. 45). “Agreement with a positively-stated proposition is hypothesized to reveal the underlying construct” of the relationship being investigated (Hodge & Gillespie, 2003, p. 45). As related to this study, using the Likert-type response formats could have been used to determine the participants’ perceptions (or attitudes) on the importance of factors related to CCPM implementation. However, there are potential problems when evaluating factors related to CCPM implementation. For instance, each of the provided CCPM implementation factors would have needed to be positively- or negatively-worded. Some factors will positively affect CCPM implementation success, some factors will negatively affect CCPM implementation success, and the way each factor affects implementation could be hypothesized but is relatively unknown. By formatting each factor into a statement that is positively- or negatively-worded, the resulting responses could have been biased one way or the other.

Another issue is that the Likert-type response format provides results that indicate how survey participants perceives each factor influences success in terms of each participant’s attitude towards the factors. Soja (2006) noted that survey participants may have a perception that a factor is important to a successful implementation based on the factor's presence in a successful implementation or the factor's absence in an unsuccessful implementation (p. 651). Soja (2006) further stated, "The respondent's estimation of a factor's importance does not capture the project conditions and does not say much about factors' influence on an implementation outcome" (p. 651). This study is, however, trying to determine what factors influence CCPM success rate. Soja (2006) demonstrated in a study of factors that influence Enterprise Resource Planning (ERP) implementations that people's perceptions of what significantly impacts implementation outcomes may not coincide with what actually influences implementation outcomes (p. 658).

Soja (2006) noted that a Likert scale from zero to five was used for respondents to estimate "the level of occurrence of each factor" (p. 652). There was an ordinal rating scale which was incorrectly identified as a Likert scale; there was not a positive or negative statement to assess an attitude, but instead an assessment of the conditions that occurred. The survey was designed for each factor using ordinal rating scales (where applicable) that measure conditions instead of opinions, as described below. (The survey is also included in Appendix C.)

- Pre-existing conditions in an organization were evaluated on a multiple choice or yes/no basis (such as industry type, project attributes, or presence of a project management office). Other factors were evaluated on an ordinal rating scale for degrees of concern (for organizational project focus) and degree of usage (for experience with other project management methodologies).
- Implementation goals were formatted to fit an ordinal rating scale for organizational degree of concern towards potential CCPM goals. Related to meeting established goals, success was evaluated in terms of degrees of increasing success.

- Features of CCPM implementation were evaluated using an ordinal rating scale in terms of degree of implementation for each feature.
- For factors related to change management and CCPM-specific factors, an ordinal rating scale was used for degree of presence of the factor (comparable to occurrence of a factor as described above).

The use of the above scales allowed the survey participants to evaluate the conditions that were occurring in the organization before, during, and after the completion of the implementation. John Flanagan developed the critical incident technique, a technique originally developed "to determine the job requirements critical for success in a variety of jobs across a number of industries" (Butterfield, Borgen, Amundson, & Maglio, 2005, p. 477). A critical incident is when observable human tasks can be "seen to lead to success or failure in accomplishing a task" (Stauss, as cited by De Saram, Ahmed, & Anson, 2004, p. 98). Therefore, an implementation event can be considered a critical incident. The preferred method for the critical incident technique is having an expert observer gather data, but many times this is not possible and other methods of data collection are used (p. 478). Butterfield et al. (2005) described the methods used for the critical incident technique, and their validity, as follows:

> He [Flanagan] spent some time gathering evidence supporting the accuracy of recalled incidents, suggesting that accuracy can be deduced from the level of full, precise details given by the participant. Flanagan advocated four ways of obtaining recalled data in the form of critical incidents: (1) individual interviews; (2) group interviews; (3) questionnaires; and (4) record forms – recording details of incidents either in narrative form or by placing a check mark beside a task on a pre-existing list of the most likely tasks to be observed. (p. 478)

From the above excerpt about the use of the critical incident technique, using the questionnaire is justified and can provide accurate information as recalled by survey participants. Survey participants were able to reflect the degrees of usage, concern, implementation, and presence for the list of factors given in the survey. For all scaling, a zero value (a value of one on the eleven-point scale) was given in case the factor was not used, not of concern, not implemented, or not present. In this manner, the survey became a way for the participants to rate the condition of each factor in addition to selecting relevant factors from a “pre-existing list of the most likely tasks” (Butterfield et al., 2005, p. 478).

Friedman (1990) studied the use of task inventories to measure the degree of redundancy between time, importance, and frequency ratings, and found that time and importance ratings may be redundant (p. 752). The time scale in the Friedman (1990) study was formatted as relative-time-spent on a seven-point scale as follows: “I spend a very small amount of time on this task as compared with most tasks I perform” to “I spend a very large amount of time on this task as compared with most other tasks I perform” (p. 749). The importance scale was a seven-point scale, ranging from “very minor” to “extreme importance” (Friedman, 1990, p. 749). The author highlights this study because some of the rating scales developed for measuring the influence of CCPM implementation had an underlying time component or importance component as measured by the survey respondent. For instance, survey participants recalled usage in comparison to a time scale and degree of concern in comparison to an importance scale. The study by Friedman (1990) implied that time and importance measures do not have to be repeated, and one can be used as an indicator of the other in analyzing survey responses.

Another aspect considered in scale development was the number of points to include in the scale. Studies have been conducted to determine if using scales with more points will have an effect on the data. Dawes (2008) found that when comparing five-point, seven-point, and ten-point scales that “none of the three formats is less desirable from the viewpoint of obtaining data that will be used for regression analysis” (p. 75). Leung (2011) compared four-point, five-point, six-point, and eleven-point scales and supported the use of eleven-point scales for ease of use, since many people are familiar with a zero through ten scale, and for a closer representation of normality (p. 420). This study, therefore, utilized an eleven-point scale.

The data was analyzed for each factor based on how the question was formatted in the survey. Chi-squared analysis for categorical questions (like industry type) was used. The chi-squared test was used to reveal if the factor had a dependent relationship with the success rate of the CCPM implementation. If so, then the relationship of the factor to high-success or low-success implementations can be determined based on the deviations between the actual counts and the expected counts for the chi-squared analysis. The Mann-Whitney Test was used on the eleven-point ordinal-scaled rating questions to test the medians between high-success and low-success implementations for each factor. The Mann-Whitney Test was chosen over a T-Test for means because the factors were determined to have non-normal distributions. Additionally, before the Mann-Whitney Test could be used, the Levene’s Test was used to ensure that the variances of the high-success and low-success implementation sample datasets were equivalent. If the variances were not equivalent for a particular factor, chi-squared analysis of that factor was used instead of the Mann-Whitney Test. The Mann-Whitney Test was used to reveal if the differences between the medians of high-success and low-success implementations for each factor were statistically significant. The relationship (positive or negative) of the factor to the success rate of the CCPM implementation was then determined from the difference between the medians.

The survey also included two additional optional questions for survey participants to complete. A condensed list of all the factors was provided and the participants were asked to provide their opinions about which five factors are the most significant in contributing to a successful CCPM implementation and which five factors are most detrimental and contribute to an unsuccessful CCPM implementation. Data collection entailed determining the highest frequency of mention for factors for successful and unsuccessful CCPM implementation, as well as notating any additional “write-in” potential factors that may not have been included in the survey. As discussed above, Soja (2006) found that there was inconsistency between what was thought to contribute to an ERP implementation and what actually influenced the ERP implementation. By collecting this optional information from survey participants, similar comparisons were made to determine if there is a mismatch between perceived importance of factors and factors found to influence CCPM implementation success rate using statistical analysis techniques.

The validity of the content deduced in the literature review was evaluated by subject matter experts on the thesis committee and by a select group of CCPM practitioners in the survey pilot test. Additionally, comment areas were included with each group of factors, in order for survey participants to include any factors that may not have been included in the survey. The interviewing process was also used to indentify factors that were overlooked or not yet identified in the literature.

Survey Administration

For this study, online surveys were used. Albaum, Wiley, Roster and Smith (2011) stated, “Internet surveys are quickly becoming the preferred method of delivery for self-administered surveys” (p. 687). Administering the survey online was selected for the following six reasons.

1. The process was faster and less expensive than using a mail process (Survey Monkey, n.d.).
2. Online surveys allowed respondents to spend as much times as needed completing the survey (Survey Monkey, n.d.).
3. Skip logic and other design features were needed (Survey Monkey, n.d.).
4. "Forced answering [an option when using online surveys] virtually eliminate[d] sources of respondent error due to item non-response" (Albaum et al., 2011, p. 687).
5. The survey needed to account for the "primacy effect" that can occur when survey participants "get into a pattern of response that does not reflect their actual thoughts" (Survey Monkey, n.d., p. 6). This issue was resolved through the online survey by ensuring that the responses within each grouping of factors were randomized with each new survey participant (Smart Survey Design, p. 6).
6. Finally, advanced tracking, including the ability to view partial responses, (Albaum et al., 2011, pp. 687, 688) was essential for tracking instances where survey responses were completed but the survey participant failed to press the "Finish" button.

Kwik Surveys (www.kwiksurveys.com) was chosen using Wadia and Parkinson's (2010) comparative guide of free online survey administration websites. The choice was made for the following reasons: an unlimited amount of surveys allowed, an unlimited number of questions, an unlimited amount of survey responses, eleven types of questions, forced answering capability, skip logic capability, editing capability once the survey was launched, the ability to download a blank survey as a Word or PDF document, the ability to browse individual responses, the ability to filter responses, and the ability to export to Microsoft Excel (Wadia & Parkinson, 2010, pp. 11-16). The types of questions allowed by Kwik Surveys were verified in respect to the discussion about the survey items and rating scales above. The capability for an eleven-point rating scale was available using a star rating scale. While this format may not be typical for this type of rating scale, the author was satisfied with the functionality and the ease of filling in ratings very quickly in a condensed format. Survey respondents do not want to spend a lot of time scrolling through questions, so a condensed format was desirable. Also, survey respondents were able to gauge their responses for factors (within the same grouping) in comparison to each other easily, as a self-calibration mechanism, to increase the quality of the responses for each individual factor.

As mentioned above, the survey was also pilot tested. The pilot test was administered to the supervising faculty member's spring 2012 classes, totaling approximately ninety students. Of these ninety students, only two responded and none had experience. Alternately, the survey link was also distributed to the thesis committee members and other contacts provided by thesis committee members that have experience with CCPM implementations (approximately twenty people). Four people with relevant CCPM experience completed the pilot test survey. The responses and input by committee subject matter experts resulted in the following determinations: the factors were all clear and easy to understand (Survey Monkey, n.d., p. 19), some improvements/changes were needed (Survey Monkey, n.d., p. 19), an estimation for survey completion time (approximately twenty minutes) and that the data collected served the purposes of the survey in terms of planned analysis (Survey Monkey, n.d., p. 19).

Critical chain project management (CCPM) gets "less than very limited used," as pointed out in the literature review (Besner & Hobbs, 2008, p. 20). Therefore, selecting participants (or a population of CCPM users) who actually have experience implementing CCPM methodology for survey distribution was difficult. The survey website link was posted on various websites, as listed in the bullet points below, in the hopes of gathering relevant experiences.

- Project Management Institute (PMI) (over 317,000 members as of November, 2011) (Goldsmith-Grandelli, personal communication, December 15, 2012). One important note is that members of PMI needed to seek participation in the survey, as there is no advertisement or notification to members about posted survey links.
- Project Management Institute's Scheduling Community of Practice (between 400 and 500 members) (Project Management Institute, n.d.). Members in this community were sent an email with the survey link in addition to having the survey link posted as an announcement and in a discussion forum on PMI's Scheduling Community website.
- CriticalChain and Critical Chain Professional LinkedIn Groups (approximately 1,500 members total) (CriticalChain, n.d.; Critical Chain Professional, n.d.). Notification to members about the survey was based on the options the individual members select regarding posting/message notifications.
- CriticalChain Yahoo! Group (between 2,000 and 3,000 members) (Ching, personal communication, February 15, 2012). Notification to members about the survey was based on the options that individual members select regarding posting/message notifications.

Responses using online surveys, according to Survey Monkey (n.d.), are typically of average quality (as opposed to good or very good quality) (p. 21). To increase the quality of the survey responses, the survey needed to manage the information received by participants by evaluating participants' knowledge and experiences and only allow survey participants with appropriate implementation experience to continue with the survey to evaluate the factors associated with CCPM implementation. Therefore, the survey responses captured online were screened to be "good" or "very good." Sometimes people may have multiple experiences implementing CCPM, such as consultants that complete different CCPM implementations. Survey participants were not restricted from completing the survey for separate CCPM implementation events and were given the option to be directed back to the beginning of the survey to complete it again for another experience. No one took advantage of this opportunity.

The survey needed to be open for a minimum of one week, but, as noted by Wadia and Parkinson (2010), two weeks is usually sufficient (p. 8). Wadia and Parkinson (2010) noted that "people tend to fill in online surveys soon after they receive the request – or not at all" (p. 8). The survey was initially distributed on March 29, 2012, to the LinkedIn CriticalChain Group and the Yahoo! CriticalChain Group and forwarded to companies that supply critical chain software for their voluntary distribution. Once the survey was approved by the Project Management Institute (PMI) on April 5, 2012, the link was posted on PMI's website. Approval for posting the survey on PMI's Scheduling Community of Practice (SCoP) took longer because a different survey was already being distributed in this community. Once the other survey had expired, the critical chain survey link for this study was posted on April 27, 2012, to SCoP's website and also distributed via email to all SCoP members. Around this same time, the researcher discovered the Critical Chain Professional LinkedIn Group and posted the survey link on April 23, 2012, in this community as well. Sending one reminder was suggested by Wadia & Parkinson (2010), while Survey Monkey (n.d.) did not specify a number but mentioned sending out "reminders" (p. 22). Reminders were given, where applicable, during the second week after the survey was opened and one week before the survey was closed. The survey was closed on May 17, 2012, to allow some of the latter groups approximately three weeks to access and complete the survey.

Interviews and Analysis

In combination with collection of data using a survey, interviews were also used identify factors that influence CCPM implementation success. The interviews also used the critical incident technique (CIT) as introduced in discussion about survey development. The CIT commonly uses interviews for data collection and analysis (Butterfield et al., 2005). The interviewing process borrowed interview style and analysis techniques from CIT, while also introducing additional comparative analysis to a survey, identical to the previously discussed survey, which was administered to interviewees directly following the interview. Using an interview process that allows participants to describe their experience in an unstructured narrative form, the interview was then analyzed for key factors that influenced the success rate of the CCPM implementation. The method was used in conjunction with the survey so that the results of each interview could be directly related to an interviewee's survey response.

The CIT steps, as outlined by Butterfield et al. (2005), are as follows: (1) ascertain the general aims of the task being studied; (2) make plans and set specifications; (3) collect the data; (4) analyze the data; and (5) interpret the data and report the results (p. 477). The goal of the interview analysis was to validate (or invalidate) the inclusion of all factors in the survey and determine other factors that can potentially influence the success rate of a CCPM implementation. Interview participation was requested from the following people: members of CriticalChain Yahoo! and LinkedIn Critical Chain group members, participants from the survey, and people that the thesis committee members identified as possible interview candidates. Both experiences with successful and unsuccessful CCPM implementations were targeted. Interviews with participants that had low-success CCPM implementations were more difficult to solicit. Gardner (2009) stated, "Failure data is always difficult to gather—people are reluctant to participate, because of the fear of impact, both to personal image, and to the organization's competitive position—anonymity is a must" (p. PM.03.2). Non-disclosure agreements were used for each interviewee and interviews were conducted via recorded phone conversations so that information from the interview was captured correctly (Butterfield et al., 2005, p. 491). (See Interview Consent Form attached in Appendix D.)

The style of the interview, according to CIT, was open-ended to allow the participants to describe the critical incident (CCPM implementation experience) in their own words (De Saram et al., 2004, p. 99). Three interview prompts were used.

1. Please describe your experience leading up to the decision to pursue critical chain project management implementation.
2. Continue with a description of your experiences related to all aspects of the critical chain project management implementation.
3. What factors during implementation of critical chain project management contributed to the success of the implementation?

There was no target number of interviews. The purpose of the interviews was to validate (or invalidate) that all factors were covered in the survey and identify some of the new factors. After completing the interview, a tracked survey, identical to the one administered in the survey section above, was sent via email. Once the data was transcribed from the interviews, data analysis was conducted. Each interview was analyzed and categorized as appropriate into the different factors, as indentified in the survey. Additional factors introduced were also categorized into the same five groupings of factors as discussed previously. Butterfield et al. (2005) suggested a robust plan for credibility and trustworthiness checks, such as the use of independent coders (p. 486). However, since the interview study was not meant to be conclusive, but instead was used to validate the survey, this step was omitted. Comparative analysis between the survey responses and the interview data was conducted to ensure consistency and correct identification of any new factors. Introduction of new factors resulted in discussion and recommendations for further studies to investigate these additional factors.

Limitations of Methodology

The factors collected in the literature review were meant to be an exhaustive list of factors that can contribute to CCPM implementation success. The assumption was made that all factors were adequately represented in the survey; however, other factors were discovered through the survey and interview process, so the value of the survey as an exhaustive tool to measure the influence of factors became limited. Comment fields in the survey, optional ranking questions, and interviews were all meant to provide study participants with the opportunity to identify additional factors that may have been missed in the survey.

Participants in the survey were self-identified from a large population of people with exposure to project work. CCPM implementations are not mainstream, and therefore, the sample may not be representative of all CCPM implementations. One hope is that through networking prompts that were included in the survey such as “Please forward this survey to anyone that might have experience with CCPM implementations,” more people with CCPM implementation experiences accessed and completed the survey. Since the survey was targeted for an unknown population and not random, determining the survey response rate was not possible.

While there are many advantages to using an online survey for this study, there were also disadvantages. One disadvantage of using online surveys was that there may have been issues when using technology that could affect participants’ ability to complete the survey (Survey Monkey, n.d.; Wadia & Parkinson, 2010). Kwik Surveys offered technical support for participants if needed. Completion of the survey also relied on participants' access to the Internet, which may have, in some cases, limited the ability to participate (Wadia & Parkinson, 2010, p. 3). Additionally, people with visual impairment may have found completing the survey difficult (Wadia & Parkinson, 2010, p. 3). An assumption was made that these issues did not introduce a measurable amount of error.

The interview process borrowed many techniques from CIT; however, some techniques suggested by CIT were purposefully omitted and may have introduced errors in the reliability of the analysis. The omission of some CIT techniques was because the purpose of the interviews was not to cover all possible factors but instead to validate or invalidate that the survey was comprehensive. Since fourteen new factors were identified and only one new factor was needed to fulfill the purpose of the interviews, this was not a concern.

Summary

The survey and interviews were carefully designed and executed to provide the information necessary for answering the research questions and to provide additional factors that may have been overlooked in the literature review or not yet identified in the literature. Surveys and interviews were targeted at a specific group of potential participants most likely to have had CCPM implementation experience. Limitations have been noted and have been addressed where possible to ensure quality data was available for analysis.

CHAPTER 5

SURVEY FINDINGS

Survey Data Preparation

The survey data was screened to ensure reliability. Duplicates based on the participants' Internet Protocol (IP) addresses were analyzed for two reasons, namely (1) to determine if duplicate responses were valid and (2) to determine if anyone took the survey multiple times for separate CCPM implementation events. As part of the survey design, participants were encouraged to take the survey multiple times for separate implementation experiences. After review, one survey was invalidated and removed because the participant first completed the survey as unfamiliar with CCPM concepts[7] and immediately re-accessed the survey to very quickly complete the entire survey (in less than six minutes) as if he or she had both knowledge and implementation experience. No one took advantage of filling out the survey multiple times for separate implementation experiences (from the same IP address).

Two other survey responses were changed to reflect less experience for the participants even though the participants completed the entire survey as if they had CCPM implementation experience. For one of these responses, the participant shared in the comments section at the end that he or she was not qualified as a respondent to fill out the survey to such detail. This person was reassigned to have "knowledge and experience but no CCPM implementation experience." Another participant shared in the comments sections within the survey that "CCPM would not have worked if used," admitting that CCPM was not actually implemented. This participant's survey was changed to reflect "knowledge and experience but no CCPM implementation experience."

[7] A survey participant that was unfamiliar with CCPM concepts was taken to the "finish" screen and did not complete other questions relating to experience with CCPM.

Survey Responses

The survey was targeted at a population of people with experience implementing CCPM. To further increase participation from this targeted group, survey participants were encouraged to forward the survey to their professional contacts as a method of snowball sampling. For instance, one survey participant posted the survey link on his personal blog. Figure 5-1 below shows a breakdown of survey responses from various outreach attempts for the 277 total surveys that were initiated by survey participants.

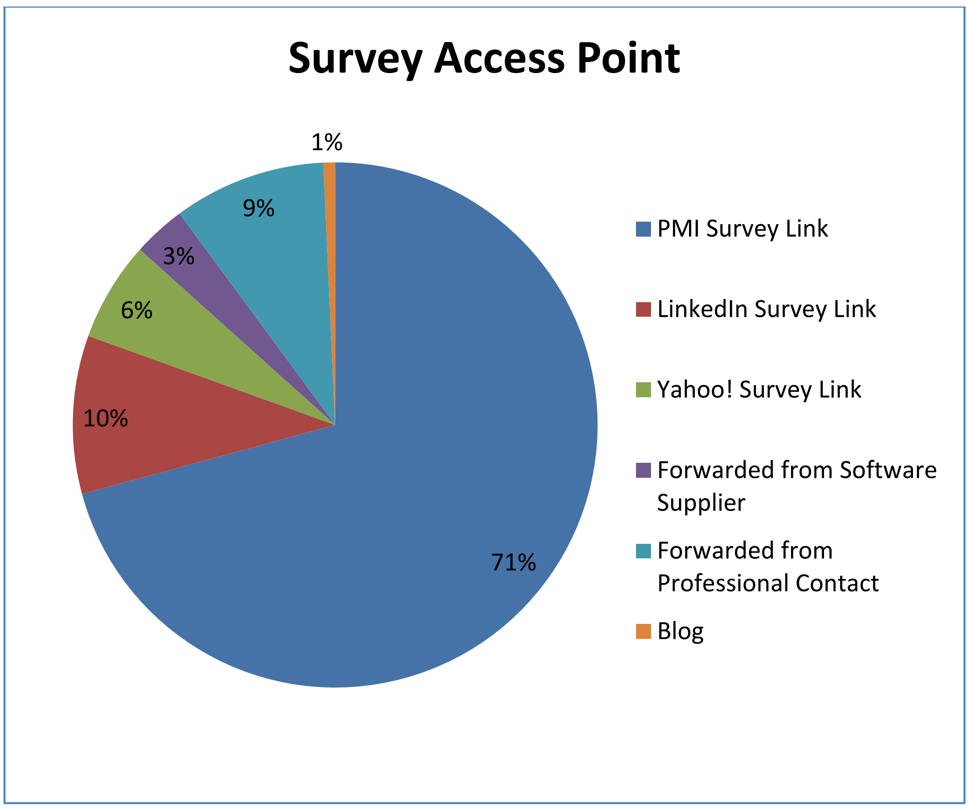

Figure 5-1. Survey access point percentages for all initiated survey responses.

A large portion (71%) of participants accessed the survey from the Project Management Institute (PMI). Participants that accessed the survey by clicking on the link from PMI's website, as opposed to accessing the link from the PMI's Scheduling Community of Practice (SCoP), were indistinguishable, so both groups are represented by "PMI Survey Link." The main reason for such strong participation from this collective group is that the entire PMI SCoP received an email with the survey link and request for participation. This group was targeted because of its members' knowledge and expertise in project scheduling techniques. Not all PMI SCoP members had the desired CCPM implementation experience, but all participants were screened for the targeted CCPM implementation experiences.

Of the 277 surveys that were started, 206 were completed each by a different individual[8]. Table 5-1 shows the completion rate of the survey based on the survey participants' knowledge and experiences. As shown in Table 5-1, 27 participants did not complete the knowledge and experience question before exiting the survey. The CCPM implementation experience category for the target survey audience had a 68% completion rate. Completing the survey with CCPM implementation experience required a greater time commitment and more detailed answering than the other knowledge and experience categories. For a survey participant with CCPM implementation experience, the number of factors in which a response was required may have been daunting enough to cause early exit from the survey.

Table 5-1.
Survey completion rates based on knowledge and experience categories

Knowledge and Experience Category	Surveys Started	Surveys Completed	% Completion
Category Not Completed	27	0	0%
CCPM Implementation Experience*	127	86	68%
Knowledge but No Experience	92	89	97%
Unfamiliar with CCPM	23	23	100%
Experience but No Implementation Experience	8	8	100%
Totals	277	206	74%

*Targeted survey responses for analysis.

[8] As discussed earlier, one duplicate survey existed in which the person first filled out the survey as unfamiliar with CCPM concepts only to return moments later and quickly fill out the survey as if he or she had experience. The duplicate was invalidated and removed and, therefore, is not reflected in this count.

There may have been other reasons why participants with implementation experience dropped out early. One reason may have been that the star rating questions were not easy to differentiate on the screen, making lining up each factor with the corresponding star rating scale difficult. Three participants commented about this issue at the end of the survey but more participants may have become frustrated with this issue before finishing the survey to comment. This issue resulted from a limitation in the formatting for the type of star rating question that was used on the survey administration website. An alternate matrix format with radial buttons may have been a better format to use. Another reason that people may have dropped out of the survey early is that all the star rating questions required an answer. People may not be comfortable saying a factor is not present and instead would prefer to choose “not applicable” instead. This option was not available with a star rating type question but would have been possible if a matrix style question had been used.

Figure 5-2 below summarizes survey participation for each knowledge and experience category in relation to how the survey was accessed. One noteworthy result is that participants that accessed the survey from PMI or the blog formed the only response groups that had less completed surveys with CCPM implementation experience when compared to the number of surveys completed in the other knowledge and experience categories. This shows that survey participants from PMI and the blog were less likely to screen themselves for CCPM implementation experience before taking the survey than the other targeted groups.

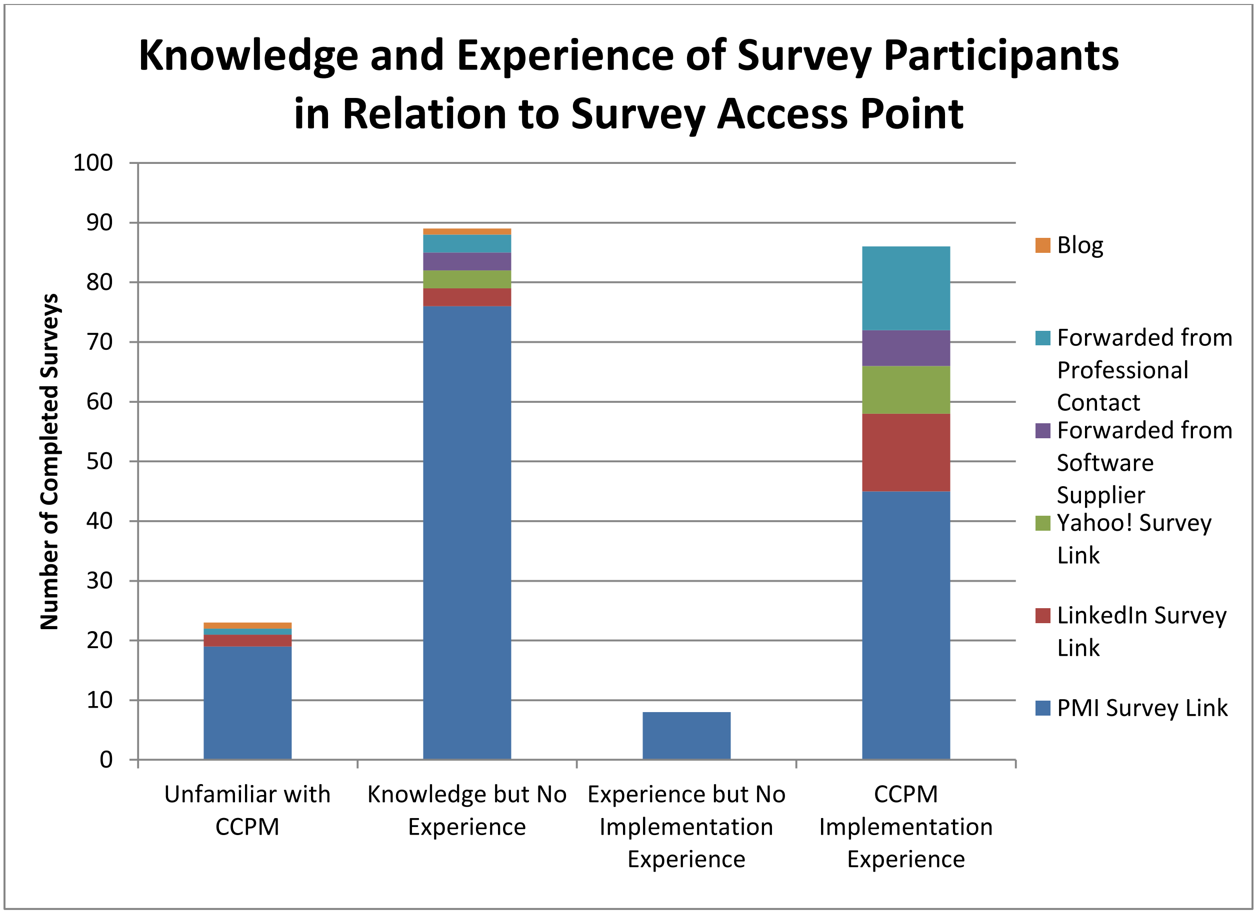

Figure 5-2. Knowledge and experience of the 206 participants in relation to survey access point.

Figure 5-3 below shows survey participants' experiences in positions in relation to CCPM knowledge and implementation experience. A larger proportion of survey participants with experience in program management, senior management, upper management, and management consulting had CCPM implementation experience compared to the other knowledge and experience categories. This may be an indicator of the role that organizational leadership and/or consultation can play in CCPM implementations, especially for multi-project implementations.

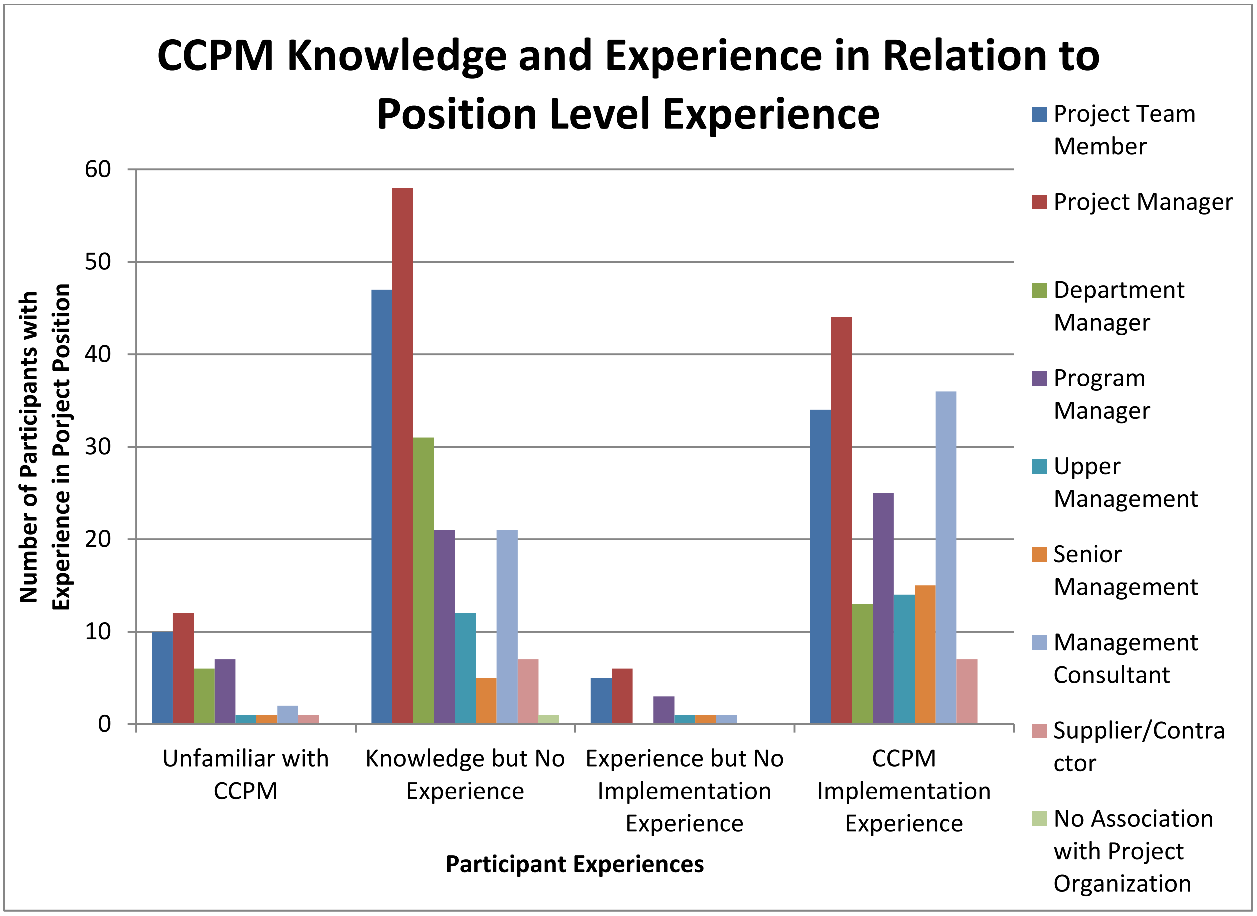

Figure 5-3. CCPM knowledge and experience of the 206 survey participants in relation to position-level experience.

Unfamiliar with CCPM

Of the 206 participants that completed the survey, 23 were unfamiliar with the CCPM concepts. No conclusions can be made about this sample in relation to the population since the survey was targeted at people that had both CCPM knowledge and implementation experience.

Knowledge but No Experience

Of the 206 participants that completed the survey, 89 had knowledge of CCPM concepts but no experience in their use. Again, no conclusion can be made about this sample in relation to the population since the survey was targeted at people that had both CCPM knowledge and implementation experience. However, a follow-up question was included for this sample of participants to see why there was CCPM knowledge but no experience. Table 5-2 is a summary of these explanatory responses.

Table 5-2.
Follow-up responses for 89 survey participants with knowledge of CCPM but no experience

I am knowledgeable about critical chain concepts but do not have any experience related to the concepts because (check all that apply)		
…the project organization that I am associated with has not implemented the concepts.	60	52%
…I am (or the project organization that I am associated with is) currently investigating implementing critical chain concepts.	17	15%
…there is no relationship between the critical chain concepts and my job.	16	14%
…I learned about critical chain concepts for a current implementation in the project organization I am associated with but have not used the critical chain concepts yet.	14	12%
…I (or the project organization that I am associated with) investigated implementing critical chain concepts but decided not to pursue implementation.	5	4%
…other.	3	3%
Total	115	100%

The results show that there are people that do not believe that critical chain is applicable (14%) as discussed in the literature review or have not decided to pursue implementation after investigation (4%). Many are associated with an organization that does not use the concepts (52%) but some are in the process of investigating CCPM implementation (15%) or currently implementing CCPM (12%). One participant commented that agile processes are not compatible with critical chain because the critical chain constantly changes in this type of environment. The survey addressed the use of CCPM in conjunction with Earned Value Management and Lean methods. Based on the above comment about Agile, the use of Agile methods in conjunction with CCPM may be an additional influential factor to consider in future CCPM research.

CCPM Experience but No Implementation Experience

Of the 206 participants that completed the survey, eight had experience with CCPM concepts but no implementation experience specifically. Participants were given the opportunity to share their alternate experiences and three elected to do so. These explanations included the following: incompatibility with contract schedule specifications for government projects, use of aspects of critical chain such as resource buffers without fully implementing CCPM, and knowledge of critical chain use in his or her organization but not enough experience with the implementation to respond about implementation details. The literature review discussed coordination with external contractors but did not address specific contract types as potential pre-existing conditions that might impact CCPM implementation success. This may be an additional factor to consider in future CCPM research.

CCPM Implementation Experience

Of the 206 participants that completed the survey, 86 had the targeted CCPM implementation experience. Multi-project and single-project implementations, even though using similar CCPM concepts, have differences in their applications in an organizational setting. The main difference is that while multi-project applications of CCPM incorporate staggering or pipelining to reduce the amount of projects that are being worked on at one time, a single-project implementation only impacts one individual project. Therefore, when analyzing the 86 completed responses, dividing these responses into multi- and single-project implementations is important.

Each of the 86 completed survey responses was analyzed to ensure that the survey responses were categorized as either multi-project or single-project implementations. The following responses for implementation type were categorized as multi-project implementations:

"I was a participant in a multi-project CCPM implementation that followed a single-project CCPM implementation pilot test" and "I was a participant in a multi-project CCPM implementation." The following responses for implementation type were categorized as single-project implementations: "I was a participant in a single-project CCPM implementation" and "I was a participant in a single-project CCPM implementation as a pilot test for a future multi-project implementation." Some people that selected "other" added comments which helped determine the project type. In three cases, the implementation type could not be distinguished from the comments, but the responses on the use of staggering projects as a CCPM feature ultimately helped to determine if the project was a multi-project or single-project implementation. In each of these three cases, the response for the level of implementation was rated high enough for "projects in a multi-project environment are deliberately staggered/pipelined" to classify the overall CCPM implementation as a multi-project implementation (nine, seven, and seven respectively on an eleven-point scale). For multi-project CCPM implementation experiences, 51 total surveys were completed. For single-project CCPM implementation experiences, 35 total surveys were completed. Figure 5-4 below shows the success rate of the implementations, as rated by the survey participants on an eleven-point scale, partitioned by project type. Below the figure, Table 5-3 shows descriptive statistics for the success rate based on the type of project and the level of success achieved, high or low.

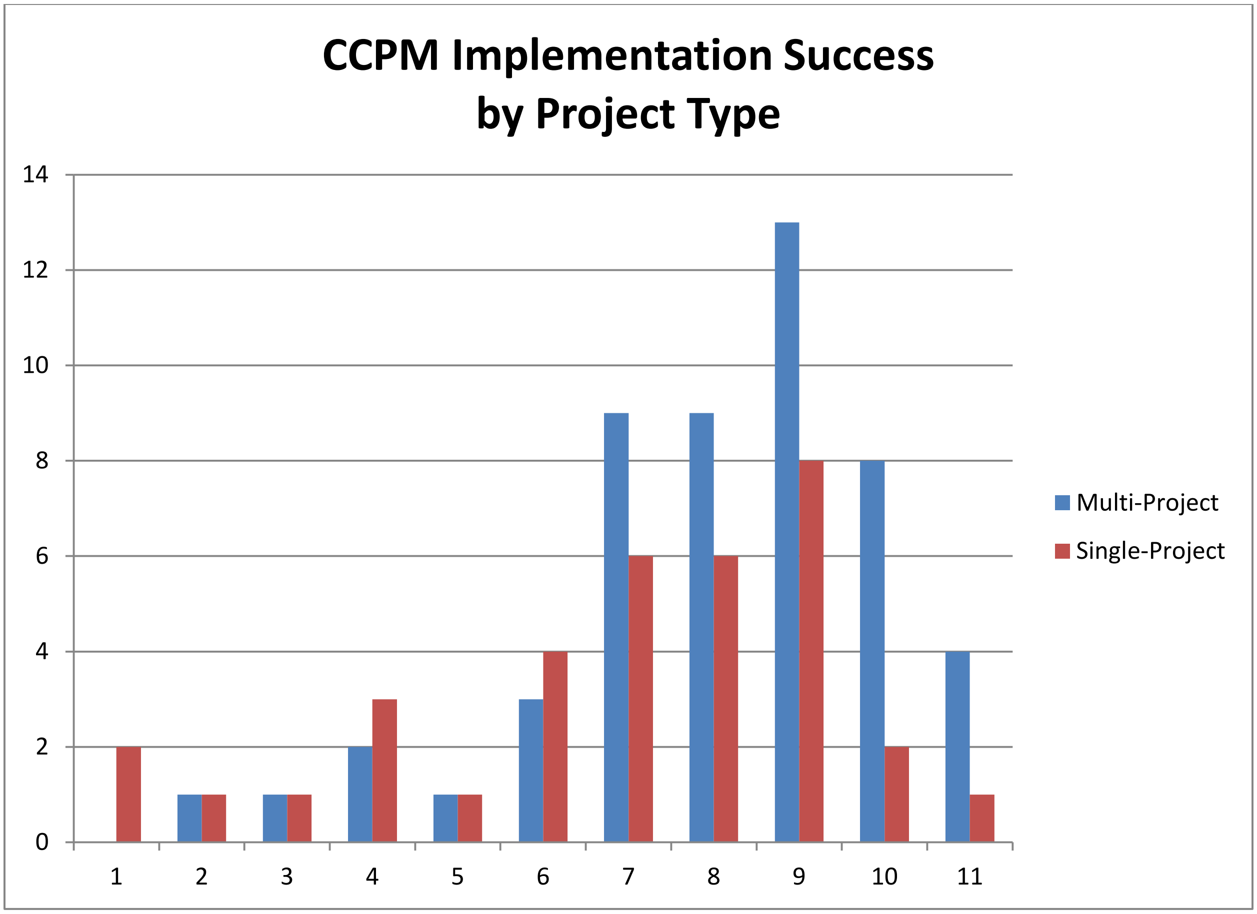

Figure 5-4. CCPM implementation success partitioned by project type (n = 86).

Table 5-3
Descriptive statistics for success rate based on CCPM implementation type.

Sample	N	Mean	Median	Standard Deviation	Min	Max
Multi-project	**51**	**8.08**	**8.0**	**2.02**	**2**	**11**
Low: Ratings 1 – 6	8	4.50	4.5	1.51	2	6
High: Ratings 7 – 11	43	8.74	9.0	1.26	7	11
Single-project	**35**	**6.89**	**7.0**	**2.54**	**1**	**11**
Low: Ratings 1 - 6	12	4.00	4.0	1.91	1	6
High: Ratings 7 – 11	23	8.39	8.0	1.12	7	11
Combined	**86**	**8.00**	**7.63**	**2.27**	**1**	**11**

The question that addressed the level of success achieved in the CCPM implementation was expressed in terms of the ability to meet intended goals/expectations for the implementation.

Survey participants shared their opinions about the success of the implementation on an eleven-point scale where ratings of one represented “no success,” ratings of two through ten represented “degrees of increasing success” and ratings of eleven represented “extremely successful.” The level of success achieved by multi-project and single-project implementations is split into “low-success” for ratings of one through six and “high-success” for ratings of seven through eleven. This splits the success ratings into two asymmetric categories. A rating of six, falling directly in the middle on the scale, was interpreted to be moderately successful but not successful enough to be included in the high-success group. To avoid the need to interpret the scale in this fashion (unequally sized groups for comparison), the scale could have been designed as a ten-point scale.

In addition to rating the success of the implementation, participants were also given the opportunity to check boxes (all that apply) for statements that further clarified success in relation to the CCPM implementation. Figure 5-5 below illustrates the distribution of descriptive success statements (in terms of value and meeting the established goals for the implementation) in relation to success ratings on the eleven-point scale. Figure 5-5 shows that a value of six is differentiated from seven because no one selected “goals exceeded” for this success rate, reinforcing the decision to link six to the low-success category for analysis.

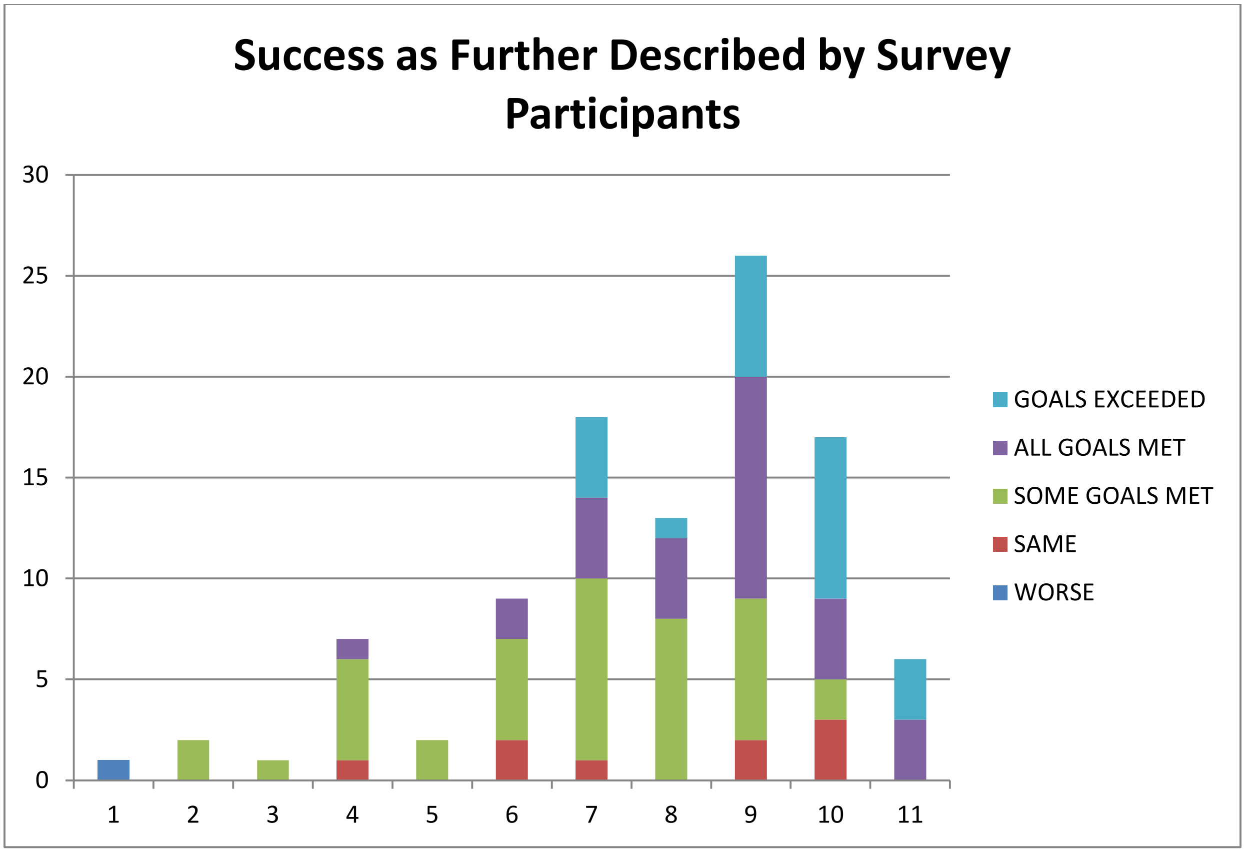

Figure 5-5. Implementation success as further described in the 86 completed survey responses.

Of the 51 multi-project implementations, 43 were categorized as high-success experiences (success rated greater than six on an eleven-point scale) and eight were categorized as low-success experiences (success rated six or less on an eleven-point scale). Of the 35 single-project implementations, 23 were categorized as high-success experiences (success rated greater than six) and twelve were categorized as low-success experiences (success rated six or less on an eleven-point scale). The more balanced number of single-project responses in terms of high-success and low-success experiences (with a mean of 6.89) provides for a more balanced comparative analysis between high-success and low-success single-project CCPM implementations in comparison to multi-project CCPM implementations (with a mean of 8.08).

Categorical Questions Analysis Results

Chi-squared analysis is used to determine if any of the categorical questions as factors are associated with CCPM implementation success. Each of the categorical question responses was set up in a frequency table based on the success of the CCPM implementation (high-success or low-success). The chi-squared analysis, using Minitab 15, is used to test for independence between variables (using the chi-squared distribution) (Minitab Inc., 2007). The null hypothesis for each categorical question is that the variables are independent. If the p-value is below the chosen alpha level of 0.05, the hypothesis is rejected and the variables are dependent. Dependency indicates that the categorical factor being tested is associated with CCPM implementation success rate based on the responses used for the analysis.

All categorical questions were analyzed regardless of the CCPM implementation type (multi-project or single-project). If more data were available, categories could be more rigorously analyzed. However, since there were only 86 completed surveys for analysis, categories for some survey questions needed to be consolidated to conduct the analysis. Table 5-4 below shows the categorical questions, their consolidated categories, the corresponding chi-squared p-values, and hypothesis test results.

Table 5-4
Chi-squared analysis results for categorical questions

Categorical Factor	Breakdown of Category	Low Success (<7) Count Expected Count	High Success (>6) Count Expected Count	P-value	Null Hypothesis[+]
Survey Access Point	PMI	11 10.47	34 34.53	0.870	Do not reject (2 cells with expected counts less than 5, 33.3%)
	Discussion Boards*	4 4.88	17 16.12		
	Forwarded*	5 4.65	15 15.35		

*Selections from survey have been combined to conduct the chi-squared analysis.
[+] Parentheses provide number of cells with expected counts less than five followed by the percentage of cells based on the number of cells in the chi-squared test.

Table 5-4
Chi-squared analysis results for categorical questions

Categorical Factor	Breakdown of Category	Low Success (<7) Count Expected Count	High Success (>6) Count Expected Count	P-value	Null Hypothesis+
Experiences in Positions	Team Member	7 7.60	27 26.40	0.999	Do not reject (2 cells with expected counts less than 5, 14.3%)
	Project Manager	10 9.83	34 34.17		
	Department Manager	3 2.90	10 10.10		
	Program Manager	5 5.59	20 19.41		
	Upper / Senior Management*	7 6.48	22 22.52		
	Management Consultant	8 8.04	28 27.96		
	Supplier / Contractor	2 1.56	5 5.44		
Implementation Type	Multi-Project	8 11.86	43 39.14	0.045	Reject
	Single Project	12 8.14	23 26.86		
Industry Type	Software, Communication, Services*	0 3.72	16 12.28	0.059	Do not reject (2 cells with expected counts less than 5, 25%)
	Construction and Engineering	9 7.67	24 25.33		
	Production	5 2.79	7 9.21		
	Government and Other*	6 5.81	19 19.19		
Presence of a PMO	Yes	11 11.86	40 39.14	0.655	Do not reject
	No	9 8.14	26 26.86		
Number of People in Organization^	0 - 100	10 7.86	23 25.14	0.469	Do not reject (1 cell with expected count less than 5, 16.7%)
	101 – 2,500	7 9.29	32 29.71		
	More than 2,500*	3 2.86	9 9.14		
Levels of Uncertainty in Task Duration Estimates^	Extremely Uncertain	3 3.76	13 12.24	0.698	Do not reject (1 cell with expected count less than 5, 16.7%)
	Moderately Uncertain	12 10.35	32 33.65		
	Moderately Certain	5 5.88	20 19.12		

*Selections from survey have been combined to conduct the chi-squared analysis.
+ Parentheses provide number of cells with expected counts less than five followed by the percentage of cells based on the number of cells in the chi-squared test.
^Responses of “don’t know” for the category were not counted.

Table 5-4
Chi-squared analysis results for categorical questions

Categorical Factor	Breakdown of Category	Low Success (<7) Count Expected Count	High Success (>6) Count Expected Count	P-value	Null Hypothesis+
Number of Tasks per Project^	0 - 400	14 10.73	6 9.27	0.092	Do not reject[1]
	More than 400*	30 33.27	32 28.73		
Financially Contributed to Organization's Bottom Line	Yes	5 9.30	35 30.70	0.028	Reject
	No	15 10.70	31 35.50		

*Selections from survey have been combined to conduct the chi-squared analysis.
[+] Parentheses provide number of cells with expected counts less than five followed by the percentage of cells based on the number of cells in the chi-squared test.
^Responses of "don't know" for the category were not counted.
[1] The null hypothesis would be rejected at a higher alpha level of 0.10. Industry type does not have this notation because the test is considered invalid per chi-squared assumptions.

Assumptions for the chi-squared analysis include that no more than 20% of the expected counts are less than five and none can be less than one for a valid test (Barnet, personal communication, May 25, 2012). For the first categorical question in the survey, survey access point, 33.3% of the cells have values below five. Even though the test is not valid according to the chi-squared analysis assumptions, the two cells containing expected counts below five were very close to five (4.88 and 4.65) and the p-value of the test is far from an alpha level of 0.05 to reject the null hypothesis. Therefore, from the data available for analysis, a dependent relationship between survey access point and implementation success rate is highly unlikely. Inclusion of completed surveys that were forwarded to software suppliers and survey responses' professional network as shown in the "forwarded" category does not appear to have introduced bias in terms of implementation success rate.

For the industry type categorical question, chi-squared results also do not meet the assumptions needed for the categorical analysis since 25% of the cells have expected counts below five. This indicates that more data is needed for this type of chi-squared analysis to ensure that conclusions are accurate. Most of the completed surveys were in the construction and engineering industry (33 out of 86 total completed surveys with CCPM implementation experience). The industry sectors were leveraged from the study by Zwikael (2009), where construction and engineering were combined into one industry sector. However, for this study, separating construction and engineering would have provided a better picture of the industries using CCPM, since many participants chose not to select “construction and engineering” and instead wrote in “engineering.” For consistency, people that entered “engineering” in the comments were grouped with the “construction and engineering” group for analysis. Other modifications were also made, such as categorizing “manufacturing” into the “production” group. The “government and other” category includes the following types of industries as entered by the survey responses: government, energy, pharmaceuticals, high-tech, research & development, electronics, telecommunications, aerospace, and education. The categories need to be revised in future studies to accurately assess the impact of industry type. Additionally, more data needs to be gathered to be able to assess the association of industry type to CCPM implementation success.

All of the other categorical questions’ chi-squared analysis results met the assumption requirements. Survey participants’ experiences in positions, the presence of a PMO in the organization, the number of people in the organization, and levels of uncertainty in task duration estimates all had p-values well above an alpha level of 0.05 at 0.999, 0.655, 0.469, and 0.698, respectively. Therefore, none of these variables demonstrate a dependency in relation to CCPM implementation success rate.

The results for implementation type, however, indicate that the type of implementation (multi-project or single-project) and CCPM implementation success are dependent variables (p-value of 0.045). This confirms that separate analysis of multi-project and single-project implementations is important in further analysis of the ordinal scale questions. The dependency, based on actual counts versus expected counts as shown in Table 5-4 above, indicates that multi-project implementations are more likely to have high-success (43 versus 39.14 expected) and, conversely, single-project applications are more likely to have low-success (12 versus 8.14 expected). If the sample is representative of all CCPM implementations, less successful single-project implementations may be more frequent because implementers might be more inclined to try CCPM on a single-project basis without being truly vested in the process. While it may be true that single-project implementations require less investment than multi-project implementations, organizations may still be under-investing in single-project implementations and therefore experiencing less success. However, one should exercise caution when examining the results, as there were a small number of low-success experiences reported for both multi- and single-project implementations (eight and twelve, respectively). The small number of low-success experiences reported might result from people's lack of interest in sharing these experiences. Future survey designs that are able to capture a larger sample with a greater quantity of less successful CCPM implementation experiences would be able to validate the initial dependency indicated by the chi-squared analysis.

There is not a dependent relationship between the number of tasks per project and CCPM implementation success (p-value of 0.092) when using an alpha level of 0.05. However, if a higher alpha level of 0.10 were used instead, dependency between the variables would be indicated. The chi-squared analysis is also used for the number of tasks per project for each implementation type to further investigate this factor (as shown in Table 5-5 below). There is not enough data for the multi-project chi-squared analysis to be valid with 50% of the cells having expected counts below five. For single-project CCPM implementations, the chi-squared test is valid and indicates that the number of tasks per project and CCPM implementation success rate are dependent variables below the alpha level of 0.05 (the p-value is 0.010). Interestingly, the lower number of tasks per project, based on counts and expected counts for the chi-squared analysis as shown in Table 5-5 below, indicates that there is a greater chance of low-success (9 versus 5.45 expected) with a lower number of tasks per project.

Table 5-5
Chi-squared analysis for number of tasks per project based on implementation type

Implementation Type	Number of Tasks per Project	Low Success (<7) Count Expected Count	High Success (>6) Count Expected Count	P-value	Null Hypothesis[+]
Multi-Project Implementation	0 – 400 tasks	5 4.73	24 24.27	0.835	Do not reject (2 cells with expected counts less than 5, 50%)
	More than 400 tasks*	3 3.27	17 16.73		
Single-Project Implementation	0 – 400 tasks	9 5.45	6 9.55	0.010	Reject
	More than 400 tasks*	3 6.55	17 11.45		

*Selections from survey have been combined to conduct the chi-squared analysis.
[+] Parentheses provide number of cells with expected counts less than five followed by the percentage of cells based on the number of cells in the chi-squared test.

Why are projects with fewer tasks more likely to be less successful in single-project CCPM implementations? One possible answer parallels the reasoning above referring to investment in the CCPM implementation process. When implementing CCPM for smaller projects (the researcher assumes number of tasks per project is directly related to project size), implementers may be less vested in the process and skip key implementation steps or not implement all of the CCPM features necessary for success. This might include, for instance, not investing time and effort to use proper change management techniques to change behaviors for such a small project. For the same size project in a multi-project environment, the scale of the multi-project implementation is larger and the organization understands the need to invest time and effort into change management. Another possible reason is that if the size of the project (in which CCPM is being implemented) is smaller, the project team members completing tasks for the project have an increasing number of other responsibilities and are unable to eliminate multitasking during the implementation.

Lastly, as part of the question asking survey participants to further describe the success rate by checking all statements that apply, there was a check box for “CCPM implementation was able to contribute financially to the organization’s bottom line.” As shown in Table 5-4 above, financial contribution to the bottom line and CCPM success rate are dependent. Based on the counts and expected counts, people that checked the box for financial contribution to the organization’s bottom line were more likely to also have a successful CCPM implementation experience (35 versus expected 30.70 in the chi-squared analysis). This does not represent causality, only a relationship in which people that measured implementation results in terms of financial contribution (and saw positive results in this measurement) also indicated a successful implementation. In the ordinal-scaled questions, another aspect of the CCPM implementation’s financial contribution to the bottom line is addressed, namely, as an established goal for the CCPM implementation. If a relationship is determined in this subsequent analysis, one could draw further inferences about this categorical factor and the significance in relationship to the CCPM implementation success rate.

Ordinal Scaled Questions Analysis Results

There are 82 remaining factors that were rated by survey responses on an eleven-point ordinal scale and analyzed using Minitab 15. The data analysis plan originally included a T-Test analysis of means. However, all of the 82 factors failed to have normal distributions when tested using the Anderson-Darling Test. Therefore, the Mann-Whitney Test (at a 95% confidence level) is used as an alternative and is a rank test of population medians (Minitab Inc., 2007). For each factor, values for the ordinal-scaled questions are separated based on how the survey respondent rated the CCPM implementation success. As described above, low-success implementations were rated as six or less and high-success implementations were rated above six. The Mann-Whitney Test evaluates the comparative data for each factor to determine if there is a statistical difference between the medians when comparing high-success and low-success implementations. The null hypothesis is that the medians are equivalent (Minitab Inc., 2007). The hypothesis is rejected based on p-values at a chosen alpha level of 0.05 (differentiated using * in the tables). Results using a higher alpha level of 0.10 (differentiated using ** in the tables) are also reported. Using a higher alpha level of 0.10 increases the chance of Type I errors (relationship between the factor and CCPM implementation success rate is falsely indicated) (Minitab Inc., 2007). However, since the quantities of low-success responses (eight for multi-project and twelve for single-project) are relatively small, relationships at an alpha level of 0.10 are displayed to avoid Type II errors (failing to identify a relationship between the factor and CCPM implementation success rate) (Minitab Inc., 2007).

Rejecting the null hypothesis for the Mann-Whitney Test will indicate an association between the factor and the CCPM implementation success rate. The negativity or positivity and magnitude of the difference between the medians will be used to indicate the type of influence that the factor has on CCPM implementation success when rejecting the null hypothesis. The factors are ordered in each of the results tables by the differences between high-success and low-success implementations from highest positive difference to the highest negative difference. For a given factor, a lower magnitude of difference between high-success and low-success implementation experiences reflects less contribution towards the success rate of the implementation when comparing high-success versus low-success implementation experiences.

Factors in which a statistical difference is not significant cannot be interpreted as being unnecessary to a CCPM implementation; instead, there is no statistical difference indicated between high-success and low-success implementations using the available data.

One of the assumptions of the Mann-Whitney Test is that the sample variances are equal (Minitab Inc., 2007). This assumption cannot be made for the data until verified using Levene's Test for equal variances and non-normal distributions based on the sample medians (Minitab Inc., 2007). For each factor, the same values for the ordinal-scaled questions are separated for high-success and low-success implementations as described above. The null hypothesis for Levene's Test is that the variances are equal (Minitab Inc., 2007). The hypothesis is rejected based on the p-values at a chosen alpha level of 0.05. If the null hypothesis for equal variance cannot be rejected for an individual factor between high-success and low-success implementations, then the Mann-Whitney Test is used as described above to determine, for an individual factor, if the difference between the medians for high-success and low-success implementations is statistically significant.

If, however, an individual factor does not have equal variances between high-success and low-success, then a chi-squared analysis will be used, similar to the categorical question analysis in the previous section, to determine the factor's potential influence towards the CCPM implementation success rate. The success rate is split as above such that success ratings of six or less are considered low-success implementations and success ratings of seven or higher are considered high-success implementations. The presence of the factor is similarly split so that a low presence of the factor is represented by six or less and a high presence of the factor is represented by seven or higher. If the null hypothesis that the variables are independent is rejected, then the difference between the medians is used as above to determine the type of influence that the factor has on CCPM implementation success rate for the dependent relationship between the variables.

The main research question is to determine which factors influence CCPM implementation success. For analysis, the 82 factors (ordinal-scaled questions) in the survey were split into the five different categories or groupings of factors that support the main research question, including pre-existing conditions in the organization, goals established for the CCPM implementation, features of CCPM that were implemented, change management factors, and CCPM-specific factors. Additionally, as indicated by the categorical analysis of implementation type, the factors are analyzed for multi-project and single-project CCPM implementations separately. There were 43 survey responses for high-success multi-project implementations versus eight survey responses for low-success multi-project implementations. There were 23 survey responses for high-success single-project implementations versus twelve survey responses for low-success single-project implementations.

Do Pre-Existing Conditions Influence CCPM Implementation Success?

The analysis of pre-existing conditions as factors that potentially influence the success rate of CCPM implementations are represented in Table 5-6 and Table 5-7 for multi- and single-project implementations, respectively. Of the 82 factors, eight are represented in the category for pre-existing conditions in an organization. There is an indication at a higher alpha level of 0.10 that existing project management (PM) practices and use of critical path method have a positive effect on the success rate for multi-project CCPM implementations (Table 5-6). Therefore, processes used as part of existing PM practices, including the use of critical path method, compliment CCPM methodology and may put an organization a step ahead on the learning curve towards a more successful multi-project CCPM implementation.

Table 5-6

Tests on pre-existing condition factors for influence (multi-project)

ID	Pre-Existing Condition Factor	High Success		Low Success		Difference between Medians	Levene's Test p-value	Mann-Whitney p-value[1]
		Median	Standard Deviation	Median	Standard Deviation			
6	Network Based Scheduling	6.0	3.07	3.0	3.14	+3.0	0.875	0.2062
5	PM Practices	7.0	3.25	4.5	3.42	+2.5	0.888	**0.0894****
3	Scope Focus	9.0	2.71	7.0	3.58	+2.0	0.081	0.1585
1	Schedule Focus	10.0	3.17	8.5	3.70	+1.5	0.634	0.2786
2	Budget Focus	8.0	3.29	6.5	3.25	+1.5	0.924	0.4019
7	Critical Path Method	7.0	3.43	5.5	2.88	+1.5	0.348	**0.0854****
4	Quality Focus	10.0	2.76	9.0	3.51	+1.0	0.649	0.6813
8	Cost/Time Tracking	8.0	2.97	7.5	3.34	+0.5	0.748	0.8958

[1] Mann-Whitney Test is conducted for 95% confidence and p-value is adjusted for ties.
**Null hypothesis rejected for higher alpha level of 0.10 for Mann-Whitney Test. This means there is a statistical significance between the difference in medians between high-success and low-success CCPM implementations at an alpha level of 0.10.

There are no indications of any pre-existing conditions that affect CCPM implementation success for single-project applications as shown in Table 5-7 for the ordinal-scaled questions. However, from the categorical question analysis, the number of tasks per project as a pre-existing condition is shown to have a dependent relationship to CCPM implementation success at an alpha level of 0.05 for a chi-squared p-value of 0.010.

Table 5-7

Tests on pre-existing condition factors for influence (single-project)

ID	Pre-Existing Condition Factor	High Success		Low Success		Difference between Medians	Levene's Test p-value	Mann-Whitney p-value[1]
		Median	Standard Deviation	Median	Standard Deviation			
6	Network Based Scheduling	6.0	3.65	4.5	3.80	+1.5	0.962	0.4828
2	Budget Focus	9.0	2.23	8.5	3.43	+0.5	0.094	0.1934
4	Quality Focus	9.0	1.83	8.5	2.99	+0.5	0.095	0.5252
1	Schedule Focus	10.0	2.66	10.5	1.73	-0.5	0.570	0.4194
3	Scope Focus	9.0	1.96	9.5	1.86	-0.5	0.787	0.6973
8	Cost/Time Tracking	6.0	3.46	6.5	3.37	-0.5	0.805	0.7398
5	PM Practices	8.0	3.23	9.0	2.27	-1.0	0.080	0.1663
7	Critical Path Method	8.0	3.32	9.5	3.49	-1.5	0.791	0.1761

[1] Mann-Whitney Test is conducted for 95% confidence and p-value is adjusted for ties.

Do CCPM Implementation Goals Affect Implementation Success?

The analysis of goal factors that potentially influence the success rate of CCPM implementations are represented in Table 5-8 and Table 5-9 for multi-project implementations and Table 5-10 for single-project implementations. Of the 82 factors, 16 are represented in this category. As shown in Table 5-8 and Table 5-9, only one factor is found to be significant for multi-project implementations, having a goal of increasing “the chance(s) that the project(s) will be completed.” Organizations that pursue this goal during implementation may have a better understanding of an existing chronic problem and can support this with baseline measurements. Buy-in for the change may be easier and measuring the success of the implementation may also be easier for organizations that want to increase the project completion percentage using CCPM.

Table 5-8

Tests on goal factors for influence (multi-project)

ID	Goal Factor	High Success		Low Success		Difference between Medians	Levene’s Test p-value	Mann-Whitney p-value[1]
		Median	Standard Deviation	Median	Standard Deviation			
14	Less Scope Changes	6.0	3.25	3.0	3.50	+3.0	0.725	0.2565
19	Project Completion Percentage	9.0	2.77	6.5	3.15	+2.5	0.414	**0.0311***
17	Manage Resources	9.0	2.92	7.0	1.13	+2.0	**0.035***	
12	On-Time Delivery	11.0	2.23	9.5	1.64	+1.5	0.997	0.1701
13	Quality	8.0	2.93	7.0	2.85	+1.0	0.408	0.2625
16	Better Prioritization	10.0	2.27	9.0	2.23	+1.0	0.552	0.9263
22	New Product Introduction	6.0	3.39	5.0	4.22	+1.0	0.130	0.3686
9	Try it Out	6.0	3.43	5.5	3.45	+0.5	0.832	0.6848
10	Faster	10.0	1.97	9.5	1.60	+0.5	0.937	0.8616
11	Increase Throughput	10.0	3.28	9.5	2.43	+0.5	0.610	0.8833
15	Less Cost Increases	7.0	3.04	6.5	3.16	+0.5	0.905	0.8347
18	Reduce Stress	6.0	3.39	6.0	2.88	0.0	0.586	0.6300
20	Reduce WIP	6.0	3.49	6.0	2.78	0.0	0.149	0.9377
24	Financial Benefits	8.0	3.41	8.0	3.63	0.0	0.913	0.6271
21	Minimize Multitasking	7.0	3.30	8.5	2.30	-1.5	0.087	0.3822
23	Charge Premiums	4.0	2.79	5.5	3.83	-1.5	0.075	0.6095

[1] Mann-Whitney Test is conducted for 95% confidence and p-value is adjusted for ties.
*Null hypothesis rejected for alpha level of 0.05. For Levene’s Test this means that the Mann-Whitney Test cannot be conducted and chi-squared analysis of the factor will need to be used instead. For Mann-Whitney this means there is a statistical significance between the difference in medians between high-success and low-success CCPM implementations.

Table 5-9

Chi-squared analysis results for goal factors (multi-project)

<table>
<tr><th>ID</th><th>Goal Factor</th><th>Presence of Factor</th><th>Low Success (<7)
Count
Expected Count</th><th>High Success (>6)
Count
Expected Count</th><th>Chi-Squared
p-value+</th></tr>
<tr><td rowspan="2">17</td><td rowspan="2">Manage Resources</td><td>Low (<7)</td><td>3
1.88</td><td>5
6.12</td><td rowspan="2">0.310
(1 cell with expected count less than 5, 25%)</td></tr>
<tr><td>High (>6)</td><td>9
10.12</td><td>34
32.88</td></tr>
</table>

+ Parentheses provide number of cells with expected counts less than five followed by the percentage of cells based on the number of cells in the chi-squared test. The chi-squared assumption for less than 20% is false, indicating that more data is needed to achieve valid chi-squared results.

For single-project implementations as shown below in Table 5-10, there are multiple goals that show significance when comparing high-success implementations over low-success implementations, including the following: speed up a new product introduction, have less scope changes, increase throughput, try it out, have less cost increases, increase project completion percentage (a shared factor between multi- and single-project applications), reduce stress, for financial benefits (at a higher alpha of 0.10), and increase quality. All relationships are positive and indicate that the greater the presence of the goal during implementation, the higher the success rate of the single-project CCPM implementation. This may be an indicator of a deeper understanding of critical chain concepts that a more successful single-project implementer has over that of a less successful implementer, meaning that other benefits of CCPM beyond the typical goals of faster projects with increased on-time completion are pursued. With a deeper understanding of CCPM concepts, the more successful implementer may also be investing more into the implementation effort by making sure necessary features are implemented and change management processes are taking place as part of the single-project CCPM implementation.

An interesting finding is that having a goal of “trying CCPM out” is not negatively associated with CCPM implementation, as suggested in the literature review. Conversely, a positive relationship is noted in Table 5-10. The same implementers that have researched and developed a deeper understanding of CCPM may be very interested in trying the CCPM method in combination with other goals. In this way, “try it out,” could be an indicator that the method was sought out by the implementer instead of being forced upon the implementer. Therefore, the circumstances surrounding the decision to pursue a single-project CCPM implementation may be additional pre-existing condition factors related to implementation success.

The goal factors are listed by the magnitude of differences and “speed up a new product introduction into the market” and “minimized scope changes for project(s)” stand out on top at 6.5 and 6.0, respectively. Speeding up a new product introduction has direct financial benefits for the company which may help gain buy-in for CCPM and give the ability to easily measure implementation success. Relating back to the discussion that the realization of financial benefits for a CCPM implementation is associated with successful implementations, one can also see that there is indication (at an alpha level of 0.10) that if goals around achieving financial benefits with a single-project implementation are established, the implementation is more likely to be successful. For the goal of minimizing scope changes, the project team may spend more time approving scope in the initial planning stages of the project in which CCPM is being implemented. Better definition of scope will minimize need for rework throughout the project and help the project team work faster towards project completion.

Table 5-10

Tests on goal factors for influence (single-project)

ID	Goal Factor	High Success		Low Success		Difference between Medians	Levene's Test p-value	Mann-Whitney p-value[1]
		Median	Standard Deviation	Median	Standard Deviation			
22	New Product Introduction	8.0	3.77	1.5	3.96	+6.5	0.788	**0.0198***
14	Less Scope Changes	9.0	3.28	3.0	3.55	+6.0	0.909	**0.0260***
11	Increase Throughput	9.0	2.97	4.5	3.54	+4.5	0.251	**0.0171***
9	Try it Out	6.0	3.44	2.0	2.72	+4.0	0.180	**0.0256***
15	Less Cost Increases	9.0	2.98	5.5	2.74	+3.5	0.863	**0.0074***
19	Project Completion Percentage	10.0	3.24	6.5	3.54	+3.5	0.435	**0.0309***
18	Reduce Stress	6.0	2.78	3.0	1.73	+3.0	0.160	**0.0011***
24	Financial Benefits	9.0	3.33	6.0	4.05	+3.0	0.138	**0.0806****
10	Faster	10.0	2.69	7.5	3.23	+2.5	0.198	0.2022
13	Quality	8.0	2.93	5.5	2.89	+2.5	0.897	**0.0440***
16	Better Prioritization	9.0	3.20	7.0	3.15	+2.0	0.937	0.2856
20	Reduce WIP	5.0	3.73	3.5	2.94	+1.5	0.171	0.3516
23	Charge Premiums	3.0	3.05	1.5	2.43	+1.5	0.101	0.2377
12	On-Time Delivery	10.0	2.83	9.5	3.68	+0.5	0.197	0.2735
17	Manage Resources	9.0	2.68	8.5	2.98	+0.5	0.642	0.4077
21	Minimize Multitasking	6.0	2.88	7.0	3.46	-1.0	0.366	0.8610

[1] Mann-Whitney Test is conducted for 95% confidence and p-value is adjusted for ties.
*Null hypothesis rejected for alpha level of 0.05. For Mann-Whitney this means there is a statistical significance between the difference in medians between high-success and low-success CCPM implementations.
**Null hypothesis rejected for higher alpha level of 0.10 for Mann-Whitney Test.

What CCPM Features Influence Implementation Success?

The analysis of CCPM features as factors that potentially influence the success rate of CCPM implementations are represented in Table 5-11 and Table 5-12 for multi-project implementations and Table 5-13 and Table 5-14 for single-project implementations. Of the 82 factors, 19 are represented in this category. There were several factors that showed significant differences between the medians for both single-project and multi-project applications. This analysis does not indicate that features with equivalent medians are not necessary features of CCPM but instead identifies where the difference in the usage of features between high-success and low-success implementations is statistically significant as an indicator of a feature's influence on implementation success. For instance, the median values for both the baseline critical chain feature and the project buffer feature in multi-project implementations for high-success and low-success are relatively high at 10.0 and 9.0, respectively. This indicates that the features are highly implemented in all cases but there is not a statistical difference in usage between the medians for high-success and low-success implementations.

For multi-project applications the following factors have differing medians between high-success and low-success implementations that are statistically significant (using the Mann-Whitney Test at an alpha level of 0.05): clear scope defined for projects, buffer recovery actions taken when needed, and rescheduling as an exception (infrequently). All three are positive relationships and use of these three features specifically can lead to a higher success rate for multi-project CCPM implementations. At a higher alpha level of 0.10, the sample data also indicates that understanding task priorities (using the priority task list) is beneficial and that the use of drum buffers negatively influences CCPM implementation success. The effect that understanding priorities and use of the priority task list have on success needs to be further validated with additional data because 25% of the cells were below five for expected counts using the chi-squared analysis which is above the 20% threshold for the chi-squared assumption.

In evaluating each of the influential factors, discussion about the low-success CCPM implementations is warranted. If clear scope is not present, rescheduling is more likely. Additionally, if scope changes and rescheduling are needed, project team members may not have a clear understanding about the priority of the project tasks. This type of changing project environment (scope changes, frequent rescheduling, and lack of understanding about priorities) appears to be incompatible with CCPM. The ability to change these conditions in the project environment should be considered and adequately addressed when implementing CCPM in the multi-project environment. Buffer management was implemented in both low-success and high-success projects as a reporting mechanism but low-success CCPM implementations did not develop plans and take action when action was indicated. Lastly, the results indicate that drum buffers[9] as a CCPM feature were found to have a negative influence on implementation success and should not be used unless justified on a case-by-case basis.

Table 5-11

Tests on CCPM features for influence (multi-project)

ID	CCPM Features as Factors	High Success		Low Success		Difference between Medians	Levene's Test p-value	Mann-Whitney p-value[1]
		Median	Standard Deviation	Median	Standard Deviation			
25	Clear Scope	10.0	2.35	6.5	3.21	+3.5	0.187	**0.0111***
37	Buffer Recovery Actions	9.0	2.43	5.5	2.72	+3.5	0.716	**0.0339***
39	Rescheduling as Exception	9.0	2.26	5.5	2.38	+3.5	0.508	**0.0092***
26	Tasks Defined	9.0	2.88	6.5	3.07	+2.5	0.795	0.4163
30	Feeding Buffers	9.0	2.84	6.5	3.87	+2.5	0.224	0.1526
41	Priority Task List	10.0	2.10	7.5	3.74	+2.5	**0.026***	
31	Resource Buffers	8.0	3.24	6.0	3.40	+2.0	0.960	0.1830
42	Road Runner Mentality	9.0	2.37	7.5	3.06	+1.5	0.198	0.2165
28	Baseline Critical Chain	10.0	2.35	9.0	2.43	+1.0	0.762	0.9681
29	Project Buffer	10.0	2.44	9.0	2.14	+1.0	0.612	0.9040
32	Milestone Buffers	7.0	3.10	6.0	3.54	+1.0	0.806	0.5842
36	Buffer Management	9.0	3.28	8.0	3.16	+1.0	0.684	0.5358
40	Minimized Multitasking	8.0	3.02	7.0	2.67	+1.0	0.435	0.7543
43	Supplier/ Contractor Integration	7.0	2.70	6.5	3.09	+0.5	0.839	0.9376
35	Projects Pipelined	9.0	3.05	9.0	2.66	0.0	0.449	0.7296
38	Remaining Task Duration Reporting	10.0	2.73	10.5	1.85	-0.5	0.487	0.5113
34	Capacity Buffers	7.0	2.83	8.0	3.66	-1.0	0.635	0.5215
27	50% Duration Estimates	8.0	3.04	9.5	1.60	-1.5	0.088	0.1260
33	Drum Buffers	6.0	3.46	9.0	3.27	-3.0	0.198	**0.0734****

[1] Mann-Whitney Test is conducted for 95% confidence and p-value is adjusted for ties.

*Null hypothesis rejected for alpha level of 0.05. For Levene's Test this means that the Mann-Whitney Test cannot be conducted and chi-squared analysis of the factor will need to be used instead. For Mann-Whitney this means there is a statistical significance between the difference in medians between high-success and low-success CCPM implementations.

**Null hypothesis rejected for higher alpha level of 0.10 for Mann-Whitney Test.

[9] Appendix B discusses each of the buffers used in CCPM. Discussion is included about drum buffers specifically as being unnecessary and confusing when used (Leach, personal communication, February 17, 2012).

Table 5-12
Chi-squared analysis results for CCPM features (multi-project)

ID	CCPM Feature as a Factor	Presence of Factor	Low Success (<7) Count Expected Count	High Success (>6) Count Expected Count	Chi-Squared p-value+
41	Priority Task List	Low (<7)	3 1.25	5 6.75	**0.065**** (1 cell with expected count less than 5, 25%)
		High (>6)	5 6.75	38 36.25	

+ Parentheses provide number of cells with expected counts less than five followed by the percentage of cells based on the number of cells in the chi-squared test. The chi-squared assumption for less than 20% is false, indicating that more data is needed to achieve valid chi-squared results.
**Null hypothesis rejected for higher alpha level of 0.10. This means at an alpha level of 0.10 there is a dependent relationship between the factor and the success of the implementation.

For single-project implementations, as shown below in Table 5-13 and Table 5-14, there are multiple features that show significance at an alpha level of 0.05 when comparing high-success implementations over low-success implementations, including the following: clearly defining the tasks in a project, using 50% duration estimates, establishing a baseline critical chain schedule, using resource buffers, reporting the status of tasks using remaining duration, creating a work environment where multitasking is minimized, and integrating suppliers / contractors into the CCPM process. The effect that reporting remaining task durations has on success needs to be further validated with additional data because 25% of the cells were below five for expected counts using the chi-squared analysis which is above the 20% threshold for the chi-squared assumption. At a higher alpha level of 0.10, using buffer recovery actions when needed, using the priority task list (understanding priorities), and working quickly on tasks and handing them off to the next resource (road-runner mentality) show indications of being beneficial in influencing CCPM success. All factors have a positive relationship where more successful implementation had higher usage rates of these features.

With such a high number of influential factors, there is an indication that the low-success single-project implementations failed to implement many of the CCPM features to a high degree.

Some of the most significant differences included supplier/contractor integration into the CCPM process, use of 50% duration estimates, use of resource buffers, and use of buffer recovery actions. For single-project applications, the results indicate that picking and choosing features and/or failing to implement features of CCPM can result in less successful implementations.

Table 5-13

Tests on CCPM features for influence (single-project)

ID	CCPM Features as Factors	High Success		Low Success		Difference between Medians	Levene's Test p-value	Mann-Whitney p-value[1]
		Median	Standard Deviation	Median	Standard Deviation			
43	Supplier/ Contractor Integration	8.0	2.84	2.5	3.70	+5.5	0.442	**0.0139***
27	50% Duration Estimates	8.0	3.17	4.0	2.89	+4.0	0.765	**0.0300***
31	Resource Buffers	7.0	3.41	3.5	2.10	+3.5	0.125	**0.0093***
37	Buffer Recovery Actions	9.0	2.79	5.5	3.28	+3.5	0.334	**0.0605****
26	Tasks Defined	8.0	2.46	5.0	3.92	+3.0	**0.050***	
28	Baseline Critical Chain	9.0	1.99	6.5	3.12	+2.5	0.084	**0.0243***
29	Project Buffer	9.0	2.98	6.5	4.48	+2.5	**0.009***	
36	Buffer Management	9.0	2.77	7.0	2.94	+2.0	0.726	0.1062
38	Remaining Task Duration Reporting	9.0	2.47	7.0	3.55	+2.0	**0.048***	
40	Minimized Multitasking	7.0	2.75	5.0	2.17	+2.0	0.363	**0.0240***
41	Priority Task List	9.0	2.25	7.5	3.15	+1.5	0.290	**0.0602****
32	Milestone Buffers	7.0	3.04	6.0	3.47	+1.0	0.421	0.1778
39	Rescheduling as Exception	8.0	3.64	7.0	3.18	+1.0	0.361	0.5397
42	Road Runner Mentality	8.0	2.03	7.0	3.03	+1.0	0.261	**0.0739****
25	Clear Scope	9.0	1.30	8.5	3.20	+0.5	**0.006***	
30	Feeding Buffers	7.0	3.16	7.0	3.59	0.0	0.834	0.7932
34	Capacity Buffers^	5.0	2.88	1.0	2.35	+4.0	0.077^	0.0119*^
35	Projects Pipelined^	5.0	3.44	2.0	2.57	+3.0	0.030*^	
33	Drum Buffers^	3.0	3.35	1.0	3.45	+2.0	0.458^	0.1056^

[1] Mann-Whitney Test is conducted for 95% confidence and p-value is adjusted for ties.
*Null hypothesis rejected for alpha level of 0.05. For Levene's Test this means that the Mann-Whitney Test cannot be conducted and chi-squared analysis of the factor will need to be used instead. For Mann-Whitney this means there is a statistical significance between the difference in medians between high-success and low-success CCPM implementations.
**Null hypothesis rejected for higher alpha level of 0.10 for Mann-Whitney Test.
^Not applicable in single-project implementations.

Table 5-14

Chi-squared analysis results for CCPM features (single-project)

ID	CCPM Feature as a Factor	Presence of Factor	Low Success (<7) Count Expected Count	High Success (>6) Count Expected Count	Chi-Squared p-value+
26	Tasks Defined	Low (<7)	8 5.14	4 6.86	**0.040***
		High (>6)	7 9.86	16 13.14	
29	Project Buffer	Low (<7)	6 4.11	6 7.89	0.157 (1 cell with expected count less than 5, 25%)
		High (>6)	6 7.89	17 15.11	
38	Remaining Task Duration Reporting	Low (<7)	6 3.43	6 8.57	**0.043*** (1 cell with expected count less than 5, 25%)
		High (>6)	4 6.57	19 16.43	
25	Clear Scope	Low (<7)	2 0.69	10 11.31	Invalid^
		High (>6)	0 1.314	23 21.69	

Note. Factor 35 from above was not analyzed using the chi-squared analysis because staggering / pipelining projects is not used in single-project CCPM implementations.

+ Parentheses provide number of cells with expected counts less than five followed by the percentage of cells based on the number of cells in the chi-squared test. If the chi-squared assumption for less than 20% is false, there is indication that more data is needed to achieve valid chi-squared results.

* Null hypothesis is rejected for alpha level of 0.05. This means that there is a dependent relationship between the factor and the success of the implementation.

^Minitab 15 was unable to calculate a p-value because the test was invalid with one cell below a value of one for the expected count.

What Change Management Factors Affect Implementation Success?

The analysis of change management factors that potentially influence the success rate of CCPM implementations are represented in Table 5-15 for multi-project implementations and Table 5-16 and Table 5-17 for single-project implementations. Of the 82 factors, 25 are represented in this category. For multi-project implementations, only three factors have statistically different medians between high-success and low-success at a higher alpha level of 0.10 including resistance (negative influence on success), communication (negative influence on success), and designing the implementation for quick wins (positive influence on success).

The absence of more influence by change management factors in multi-project CCPM implementations is a surprising finding in comparison to the significance of change management efforts pointed out in the literature review and other research studies. For example, in a yearly study conducted by Prosci for best practices in change management, having a champion from upper management lead and participate in the change effort has been identified every year as the most influential factor in change management success, and in the 2012 study, by four times as much as any other factor (Creasey, 2012). In this study, the champion's presence and participation is not significantly different between median values for high-success and low-success implementations (9.0 and 9.5, respectively). This shows that of the eight low-success multi-project implementation experiences shared, all were probably aware of and using change management best practices for the CCPM implementation effort. For instance, the median value for the CCPM effort planned as a project is very high with a value 9.5 on an eleven-point scale for low-success CCPM implementations, as are many of the other change management factors. The results from the multi-project analysis, therefore, do not address the influence of the need for change management but instead identifies factors that influence the success rate despite best efforts to use change management for the CCPM implementation effort. The results are then significant in that even though change management techniques were used, designing the CCPM implementation effort to achieve "quick wins" influences success while the presence of too much communication (maybe instead of less but more focused communication efforts) and the presence of resistance can negatively impact CCPM implementation success.

Table 5-15

Tests on change management factors for influence (multi-project)

ID	Change Management Factor	High Success		Low Success		Difference between Medians	Levene's Test p-value	Mann-Whitney p-value[1]
		Median	Standard Deviation	Median	Standard Deviation			
65	Quick Wins	9.0	2.77	6.5	3.46	+2.5	0.231	**0.0786****
67	Customization to Build Ownership	8.0	3.02	6.0	3.65	+2.0	0.463	0.7935
64	At-End Measurements	9.0	2.84	7.5	3.25	+1.5	0.618	0.7432
66	Performance Management Reinforcement	7.0	3.12	5.5	3.46	+1.5	0.760	0.5757
47	Urgency	8.0	3.16	7.0	3.23	+1.0	0.953	0.7537
55	Software Functionality	9.0	3.24	8.0	3.37	+1.0	0.925	0.2748
53	Change Agents	8.0	2.95	7.5	3.55	+0.5	0.629	0.7741
56	Software Integration	6.0	3.38	5.5	3.58	+0.5	0.799	0.6674
44	Buy-In Established	8.0	2.80	8.0	3.11	0.0	0.701	0.9063
51	Vision	9.0	3.08	9.0	2.71	0.0	0.829	1.0000
60	Review Basic PM Concepts	8.0	3.08	8.0	2.60	0.0	0.370	0.5646
61	Practical Training	8.0	3.35	8.0	3.51	0.0	0.701	1.0000
63	Incremental Measurements	6.0	2.99	6.0	2.66	0.0	0.333	0.6673
49	Champion Participation	9.0	3.14	9.5	3.64	-0.5	0.896	0.9580
58	External Consultants	8.0	3.97	8.5	4.10	-0.5	0.913	0.9151
68	Planned as Project	9.0	2.80	9.5	2.77	-0.5	0.984	0.7920
48	Champion	9.0	2.89	10.0	3.70	-1.0	0.933	0.4541
57	Role Changes/ Integration	8.0	2.97	9.0	3.83	-1.0	0.482	0.9583
45	Buy-In Maintained	7.0	2.69	8.5	4.17	-1.5	0.128	0.8757
52	Communication	8.0	2.71	9.5	2.45	-1.5	0.307	**0.0968****
59	Training Adequate	8.0	3.40	9.5	3.66	-1.5	0.807	0.2962
62	Early Software Training	7.0	3.71	8.5	3.73	-1.5	0.713	0.4311
54	Stakeholder Involvement	6.0	3.03	8.0	3.62	-2.0	0.936	0.7946
46	Resistance	7.0	2.66	9.5	2.59	-2.5	0.632	**0.0827****
50	Anti-Champion	4.0	2.91	7.5	2.55	-3.5	0.401	0.4173

[1] Mann-Whitney Test is conducted for 95% confidence and p-value is adjusted for ties.

**Null hypothesis rejected for higher alpha level of 0.10 for Mann-Whitney Test. This means there is a statistical significance between the difference in medians between high-success and low-success CCPM implementations at an alpha level of 0.10.

For single-project implementations, nine factors, at an alpha level of 0.05, are positively associated with successful CCPM implementations. These include the following: buy-in initially established, buy-in maintained throughout implementation, vision established for implementation effort, stakeholder involvement in the process, software provided needed functionality, role and responsibility changes are integrated in the process, training is adequate, incremental measurements for the success of the implementation are used, and the implementation is designed for quick wins (only shared influential factor between multi-project and single-project implementations). Additionally, at a higher alpha level of 0.10, presence of a champion from upper management, participation of this champion throughout the implementation effort, use of performance management system to reinforce CCPM behaviors, use of customization of the CCPM implementation to build ownership in the process, planning the CCPM implementation as a project, and use of at-end measurements for implementation success all showed indication of positive association with more successful single-project CCPM implementations. The effect that at-end measurements have on success needs to be further validated with additional data because 25% of the cells were below five for expected counts using the chi-squared analysis, which is above the 20% threshold for the chi-squared assumption.

Unlike low-success experiences for multi-project CCPM implementations, low-success single-project CCPM implementations have much lower median values for change management factors. For instance, looking at a few of the statistically significant differences between typical change management factors, high-success implementations made use of more change management best practices. For instance, the median values for establishing buy-in were 8.0 for high-success implementations versus 3.0 for low-success implementations. For adequate training the median values were 8.0 for high-success and 2.5 for low-success implementations. Another example is champion participation where the median values were 9.0 for high-success and 5.5 for low-success implementations. There is an indication that the use of proper change management techniques is significant to the success rate of single-project CCPM implementations.

The single-project comparisons between high successes and low successes highlight which change management factors are most influential. Some of the most significant change management factors (+4 or higher for differences between medians) include stakeholder involvement, training (three different factors related to training), incremental measurements, buy-in, vision, and integration of role/responsibility changes. Stakeholder involvement as the top influential factor refers to "peripheral stakeholders such as customers/suppliers involved in CCPM implementation." Single-project CCPM implementations that do not take into account the impact on peripheral stakeholders and do not adequately address CCPM training needs for the project teams are less successful.

Table 5-16

Tests on change management factors for influence (single-project)

ID	Change Management Factor	High Success		Low Success		Difference between Medians	Levene's Test p-value	Mann-Whitney p-value[1]
		Median	Standard Deviation	Median	Standard Deviation			
54	Stakeholder Involvement	8.0	2.80	1.5	3.40	+6.5	0.888	**0.0091***
59	Training Adequate	8.0	2.71	2.5	2.93	+5.5	0.676	**0.0044***
63	Incremental Measurements	7.0	2.45	2.0	3.15	+5.0	0.328	**0.0061***
44	Buy-In Established	8.0	3.16	3.5	2.66	+4.5	0.548	**0.0263***
51	Vision	7.0	2.57	2.5	3.84	+4.5	0.314	**0.0125***
57	Role Changes/ Integration	6.0	3.32	1.5	2.90	+4.5	0.538	**0.0464***
61	Practical Training	8.0	3.65	3.5	3.74	+4.5	0.746	0.3690
62	Early Software Training	6.0	3.44	2.0	3.49	+4.0	0.809	0.1209
49	Champion Participation	9.0	2.69	5.5	3.50	+3.5	0.337	**0.0996****
55	Software Functionality	7.0	3.46	3.5	3.20	+3.5	0.884	**0.0401***
67	Customization to Build Ownership	7.0	3.04	3.5	2.83	+3.5	0.971	**0.0502****
45	Buy-In Maintained	8.0	2.83	5.0	2.43	+3.0	0.642	**0.0104***
60	Review Basic PM Concepts	9.0	2.94	6.0	3.70	+3.0	0.205	0.1259
65	Quick Wins	7.0	2.86	4.0	2.98	+3.0	0.656	**0.0357***
66	Performance Management Reinforcement	7.0	3.17	4.0	3.33	+3.0	0.427	**0.0652****
68	Planned as Project	6.0	3.07	3.0	3.58	+3.0	0.623	**0.0894****
48	Champion	7.0	2.92	4.5	3.77	+2.5	0.195	**0.0991****
58	External Consultants	6.0	3.51	4.0	4.02	+2.0	0.557	0.2319
64	At-End Measurements	8.0	2.13	6.0	3.49	+2.0	**0.024***	
52	Communication	7.0	1.80	5.5	3.85	+1.5	**0.000***	
56	Software Integration	4.0	3.13	3.0	3.02	+1.0	0.707	0.3160
53	Change Agents	6.0	3.16	5.5	3.07	+0.5	0.872	0.1561
50	Anti-Champion	5.0	3.74	5.0	3.94	0.0	0.992	0.9441
46	Resistance	7.0	2.55	8.0	3.36	-1.0	0.495	0.4718
47	Urgency	6.0	3.09	7.0	3.41	-1.0	0.875	0.5879

[1] Mann-Whitney Test is conducted for 95% confidence and p-value is adjusted for ties.

*Null hypothesis rejected for alpha level of 0.05. For Levene's Test this means that the Mann-Whitney Test cannot be conducted and chi-squared analysis of the factor will need to be used instead. For Mann-Whitney this means there is a statistical significance between the difference in medians between high-success and low-success CCPM implementations.

**Null hypothesis rejected for higher alpha level of 0.10 for Mann-Whitney Test.

Table 5-17
Chi-squared analysis results for change management factors (single-project.

ID	Change Management Factor	Presence of Factor	Low Success (<7) Count Expected Count	High Success (>6) Count Expected Count	Chi-Squared p-value+
64	At-End Measurements	Low (<7)	7 4.46	5 7.54	**0.061**** (1 cell with expected count less than 5, 25%)
		High (>6)	6 8.54	17 14.46	
52	Communication	Low (<7)	7 5.14	5 6.86	0.181
		High (>6)	8 9.86	15 13.14	

+ Parentheses provide number of cells with expected counts less than five followed by the percentage of cells based on the number of cells in the chi-squared test. If the chi-squared assumption for less than 20% is false, there is indication that more data is needed to achieve valid chi-squared results.
**Null hypothesis rejected for higher alpha level of 0.10. This means at an alpha level of 0.10 there is a dependent relationship between the factor and the success of the implementation.

What CCPM-specific factors influence implementation success?

The analysis of CCPM-specific factors that potentially influence the success rate of CCPM implementations are represented in Table 5-18 for multi-project CCPM implementations and Table 5-19 and Table 5-20 for single-project CCPM implementations. Of the 82 factors, 14 are represented in this category. The most significant CCPM-specific factor is that with an increased presence of satisfaction about the method used for determining task durations, there is a greater realization of multi-project CCPM implementation success (at an alpha level of 0.05). Assessing this finding in conjunction with the finding of resistance as a factor for change management, resistance around the use of the task duration method specifically may be present in the low-success multi-project CCPM implementation.

At a higher alpha level of 0.10 for multi-project CCPM implementations, there is an increased desire for a CCPM standard with high-success implementations. This is an unexpected finding, since the lack of a standard was identified as a contributor to failed CCPM implementations in the literature review (Lechler et al., 2005a), where here the desire for a CCPM standard is positively related with success. This most likely demonstrates that the wording for the survey did not address the factor about the lack of a CCPM standard as a contributor to failure. Implementers that had success with CCPM are probably more likely to want additional information available in the form of a standard or have created a standard themselves as part of the implementation. Conversely, low-success implementers may be frustrated and are not interested in seeking out more information in the form of a standard and did not create their own standard as part of the implementation. Instead of using the presence of "desire for a CCPM standard," a future survey could address the impact that the lack of standard had on an implementation by using alternate phrasing such as presence of "negative impact due to lack of CCPM standard."

Table 5-18

Tests on CCPM-specific factors for influence (multi-project)

ID	CCPM-Specific Factor	High Success		Low Success		Difference between Medians	Levene's Test p-value	Mann-Whitney p-value[1]
		Median	Standard Deviation	Median	Standard Deviation			
69	Desire for Standard	8.0	3.14	3.5	3.59	+4.5	0.763	**0.0875****
70	Task Duration Method	7.0	2.58	3.0	2.56	+4.0	0.924	**0.0059***
81	Non-Project Work	8.0	3.47	6.0	2.90	+2.0	0.300	0.2509
71	Buffer Duration Method	8.0	2.60	7.0	3.63	+1.0	0.160	0.2727
77	Coordination with External Suppliers	5.0	3.07	4.0	2.72	+1.0	0.298	0.3347
79	Complexity of Method	5.0	3.02	4.5	3.14	+0.5	0.971	0.8654
72	Conflict Over Duration Methods	5.0	3.22	5.0	2.93	0.0	0.740	0.9896
76	Focused Work	6.0	2.47	6.0	2.83	0.0	0.539	0.3956
78	Delayed Starts	5.0	3.53	5.5	3.50	-0.5	0.859	0.8845
73	Baseline Schedule	3.0	3.30	4.0	2.97	-1.0	0.722	0.5184
80	Earned Value	2.0	3.73	3.0	3.01	-1.0	0.683	0.9783
75	Management Interruptions	5.0	3.31	6.5	3.02	-1.5	0.561	0.3896
82	Lean Methods	5.0	3.5807	7.0	3.34	-2.0	0.599	0.8239
74	Reprioritization	6.0	3.10	8.5	3.27	-2.5	0.851	0.3832

[1] Mann-Whitney Test is conducted for 95% confidence and p-value is adjusted for ties.
*Null hypothesis rejected for alpha level of 0.05. For Mann-Whitney this means there is a statistical significance between the difference in medians between high-success and low-success CCPM implementations.
**Null hypothesis rejected for higher alpha level of 0.10 for Mann-Whitney Test.

For single-project CCPM implementations, other CCPM-specific factors emerged as significant in association with the success rate of the implementation. At an alpha level of 0.05, presence of a desire for a CCPM standard, presence of an environment where focused work was possible, presence of a perception that the CCPM method was too complex, and presence of issues cause by delayed starts are associated with increased success for single-project CCPM implementations. A desire for a CCPM standard is positively correlated, as discussed above for multi-project CCPM, and being able to complete focused work was also positively correlated. Presence of complexity of the method and issues with delayed starts are negatively correlated with single-project CCPM implementation success. At a higher alpha level of 0.10, presence of satisfaction for the task duration method used was positively correlated with successful single-project implementations (like with multi-project implementations) and presence of management interruptions was negatively correlated with single-project implementation success.

Many of the CCPM-specific factors may be related when considering low-success implementations. For instance, possible problems associated with delayed starts may have been one of the main reasons why implementers felt that CCPM was too complex. For delayed starts to be effective when using CCPM, the correct logical relationships need to be defined for each task. If the project planners are not comfortable defining these relationships, this need might be viewed as addition of unnecessary complexity to the process. The delayed starts, even when the logical relationships are defined properly, may have caused issues in the project in an environment where focused work was not possible. If a resource is unable to focus on a task and instead continues to multitask, delaying starts of tasks may cause problems on the critical chain when feeding tasks take longer than necessary. One of the contributors to multitasking is responding to management inquiries. The results indicate that the presence of management interruptions negatively impacted the level of success achieved in single-project implementations.

Table 5-19

Tests on CCPM-specific factors for influence (single-project)

ID	CCPM-Specific Factor	High Success		Low Success		Difference between Medians	Levene's Test p-value	Mann-Whitney p-value[1]
		Median	Standard Deviation	Median	Standard Deviation			
69	Desire for Standard	9.0	2.98	3.5	3.00	+5.5	0.972	**0.0027***
80	Earned Value	6.0	4.14	1.5	4.14	+4.5	0.410	0.5249
76	Focused Work	7.0	2.29	3.0	3.26	+4.0	**0.039***	
70	Task Duration Method	8.0	2.36	6.0	3.20	+2.0	0.357	**0.0760****
82	Lean Methods	5.0	3.34	3.0	3.37	+2.0	0.825	0.3459
71	Buffer Duration Method	8.0	2.21	6.5	3.34	+1.5	0.080	0.3328
74	Reprioritization	7.0	3.23	6.5	3.92	+0.5	0.385	0.5284
73	Baseline Schedule	5.0	3.14	5.5	3.17	-0.5	0.701	0.9165
81	Non-Project Work	8.0	3.01	9.5	3.15	-1.5	0.922	0.1353
72	Conflict Over Duration Methods	4.0	3.11	6.0	3.81	-2.0	0.303	0.2940
77	Coordination with External Suppliers	3.0	3.01	5.0	4.12	-2.0	0.284	0.4572
79	Complexity of Method	4.0	3.27	6.0	3.20	-2.0	0.835	**0.0499***
75	Management Interruptions	3.0	3.07	5.5	3.50	-2.5	0.593	**0.0974****
78	Delayed Starts	4.0	2.82	6.5	3.65	-2.5	0.218	**0.0441***

[1] Mann-Whitney Test is conducted for 95% confidence and p-value is adjusted for ties.
*Null hypothesis rejected for alpha level of 0.05. For Levene's Test this means that the Mann-Whitney Test cannot be conducted and chi-squared analysis of the factor will need to be used instead. For Mann-Whitney this means there is a statistical significance between the difference in medians between high-success and low-success CCPM implementations.
**Null hypothesis rejected for higher alpha level of 0.10 for Mann-Whitney Test.

Table 5-20

Chi-squared analysis results for CCPM -specific factors (single-project)

ID	CCPM-Specific Factor	Presence of Factor	Low Success (<7) Count Expected Count	High Success (>6) Count Expected Count	Chi-Squared p-value
76	Focused Work was Possible	Low (<7)	9 5.83	3 6.17	**0.024***
		High (>6)	8 11.17	15 11.83	

*Null hypothesis rejected for alpha level of 0.05 for chi-squared test. This means that there is a dependent relationship between the factor and the success of the implementation.

For CCPM-specific factors, the difference between median values between high-success implementations versus low-success implementations in reference to the identification of the need for a CCPM standard is large for both single-project and multi-project applications (+4.5 and +5.5, respectively). Creating a CCPM standard may also help increase the success rate for CCPM implementers that are struggling with the concepts. One of the most important factors to address in such a standard, as identified in both multi-project and single-project implementations, is to identify best practices around the method for determining task durations. Identifying best practices and clearing up some of the resistance around the use of 50% task durations, as identified by critics of CCPM in the literature review, may help CCPM implementation efforts be more successful.

Multi-Project and Single-Project Combined Analysis

The separation of multi-project and single-project CCPM implementations was necessary. However, are there factors that share a consistent influence on CCPM implementation success across multi-project and single-project implementations? Before conducting this analysis, the equivalency of medians for each factor between high-success multi-project and high-success single-project implementations and, separately, between low-success multi-project and low-success single-project implementations was assessed. This was to ensure that for each factor there was not a significant difference between medians between the high-success groups or a difference between the medians between the low-success groups for the two types of implementations (multi-project and single-project). If the null hypothesis was rejected for equivalent variances (Levene's Test) or the null hypothesis for equivalent medians was rejected (Mann-Whitney Test) for an individual factor, then the combined analysis was not justified for that factor.

As with the process described above, to use the Mann-Whitney Test for equivalent medians, Levene's Test for equivalent variances was conducted first. As warranted per the results of the Levene's Test (at an alpha level of 0.05), the responses for multi-project high successes and single-project high successes were tested for equivalency of medians using the Mann-Whitney Test at an alpha level of 0.05. Similarly, as warranted per the results of the Levene's Test (at an alpha level of 0.05), responses for multi-project low successes and single-project low successes were tested for equivalent medians. If, for each individual factor, the null hypothesis of equivalency was not rejected both for high successes and for low successes, multi-project and single-project high-success responses were combined and multi-project and single-project low-success responses were combined so that all high successes and all low successes could be comparatively analyzed as combined data for both types of implementations. Of the 82 factors, there was justification for analysis of 44 factors using the combined data for both types of implementations. The combined data includes 66 high-success CCPM implementations (success ratings greater than six) and 20 low-success CCPM implementations (success ratings less than seven). Table 5-21 and Table 5-22 below show the results of the 44 factors tested using combined CCPM implementation data for both types of implementations.

Table 5-21

Tests on factors for all CCPM implementations combined (multi-project and single-project)

ID	Factor	High Success		Low Success		Difference between Medians	Levene's Test p-value	Mann-Whitney p-value[1]
		Median	Standard Deviation	Median	Standard Deviation			
22	Goal: New Product Introduction	7.0	3.53	2.0	4.01	+5.0	0.618	**0.0148***
69	CCPM: Desire for Standard	8.0	3.09	3.5	3.17	+4.5	0.876	**0.0007***
31	Feature: Resource Buffers	8.0	3.28	4.0	2.76	+4.0	0.565	**0.0019***
19	Goal: Project Completion Percentage	10.0	2.92	6.5	3.31	+3.5	0.237	**0.0016***
37	Feature: Buffer Recovery Actions	9.0	2.58	5.5	3.01	+3.5	0.223	**0.0016***
54	Change: Stakeholder Involvement	6.0	2.94	2.5	3.75	+3.5	0.171	**0.0357***
26	Feature: Tasks Defined	8.0	2.73	5.5	3.60	+2.5	0.059	**0.0738****
6	Pre-existing: Network Based Scheduling	6.0	3.26	4.0	3.63	+2.0	0.641	0.8050
13	Goal: Quality	8.0	2.91	6.0	2.83	+2.0	0.610	**0.0180***
42	Features: Road Runner Mentality	9.0	2.26	7.0	3.02	+2.0	0.120	**0.0086***
49	Change: Champion Participation	9.0	2.97	7.0	3.63	+2.0	0.204	0.1559
58	Change: External Consultants	7.0	3.80	5.0	4.12	+2.0	0.469	0.2668
60	Change: Review Basic PM Concepts	9.0	3.01	7.0	3.28	+2.0	0.454	0.1164
64	Change: At End Measurements	8.5	2.60	6.5	3.39	+2.0	0.069	0.1219
76	CCPM: Focused Work	7.0	2.42	5.0	3.14	+2.0	**0.049***	
8	Pre-existing: Cost/Time Tracking	8.0	3.15	6.5	3.33	+1.5	0.851	0.6317
10	Goal: Faster	10.0	2.24	8.5	2.83	+1.5	0.109	0.1645
17	Goal: Manage Resources	9.0	2.83	7.5	2.37	+1.5	0.447	**0.0266***
45	Change: Buy-In Maintained	7.0	2.71	5.5	3.34	+1.5	0.186	**0.0499***
53	Change: Change Agents	8.0	3.02	6.5	3.36	+1.5	0.568	0.0787**

[1] Mann-Whitney Test is conducted for 95% confidence and p-value is adjusted for ties.
*Null hypothesis rejected for alpha level of 0.05. For Levene's Test this means that the Mann-Whitney Test cannot be conducted and chi-squared analysis of the factor will need to be used instead. For Mann-Whitney this means there is a statistical significance between the difference in medians between high-success and low-success CCPM implementations.
**Null hypothesis rejected for higher alpha level of 0.10 for Mann-Whitney Test.

Table 5-21

Tests on factors for all CCPM implementations combined (multi-project and single-project)

ID	Factor	High Success		Low Success		Difference between Medians	Levene's Test p-value	Mann-Whitney p-value[1]
		Median	Standard Deviation	Median	Standard Deviation			
66	Change: Performance Management Reinforcement	7.0	3.12	5.5	3.42	+1.5	0.422	**0.0450***
70	CCPM: Task Duration Method	7.0	2.50	5.5	3.03	+1.5	0.125	**0.0037***
71	CCPM: Buffer Duration Method	8.0	2.46	6.5	3.37	+1.5	**0.037***	
82	CCPM: Lean Methods	5.0	3.47	3.5	3.36	+1.5	0.938	0.4907
25	Feature: Clear Scope	9.0	2.04	8.0	3.27	+1.0	**0.014***	
32	Feature: Milestone Buffers	7.0	3.06	6.0	3.41	+1.0	0.461	0.1605
36	Feature: Buffer Management	9.0	3.09	8.0	2.99	+1.0	0.974	**0.0904****
1	Pre-existing: Schedule Focus	10.0	2.98	9.5	2.81	+0.5	0.906	0.8860
12	Goal: On-Time Delivery	10.0	2.45	9.5	3.07	+0.5	0.152	**0.0452***
24	Goal: Financial Benefits	8.0	3.38	7.5	3.80	+0.5	0.261	**0.0974****
47	Change: Urgency	7.5	3.13	7.0	3.25	+0.5	0.970	1.0000
61	Change: Practical Training	8.0	3.45	7.5	3.74	+0.5	0.380	0.2615
4	Pre-existing: Quality Focus	9.0	2.46	9.0	3.12	0.0	0.228	0.3306
56	Change: Software Integration	5.0	3.32	5.0	3.27	0.0	0.794	0.1587
80	CCPM: Earned Value	2.0	3.90	2.0	3.65	0.0	0.533	0.6998
72	CCPM: Conflict Over Duration Methods	5.0	3.19	6.0	3.42	-1.0	0.639	0.4625
78	CCPM: Delayed Starts	5.0	3.33	6.0	3.54	-1.0	0.748	0.1496
21	Goal: Minimize Multitasking	6.0	3.16	7.5	3.17	-1.5	0.799	0.6923
50	Change: Anti-Champion	4.5	3.20	6.0	3.39	-1.5	0.856	0.6035
74	CCPM: Reprioritization	6.0	3.12	7.5	3.60	-1.5	0.202	0.2785

[1] Mann-Whitney Test is conducted for 95% confidence and p-value is adjusted for ties.
*Null hypothesis rejected for alpha level of 0.05. For Levene's Test this means that the Mann-Whitney Test cannot be conducted and chi-squared analysis of the factor will need to be used instead. For Mann-Whitney this means there is a statistical significance between the difference in medians between high-success and low-success CCPM implementations.
**Null hypothesis rejected for higher alpha level of 0.10 for Mann-Whitney Test.

Table 5-21

Tests on factors for all CCPM implementations combined (multi-project and single-project)

ID	Factor	High Success		Low Success		Difference between Medians	Levene's Test p-value	Mann-Whitney p-value[1]
		Median	Standard Deviation	Median	Standard Deviation			
46	Change: Resistance	7.0	2.60	9.0	3.11	-2.0	0.639	0.1026
73	CCPM: Baseline Schedule	3.0	3.25	5.0	3.03	-2.0	0.558	0.4603
75	CCPM: Management Interruptions	4.0	3.25	6.0	3.24	-2.0	0.875	0.1038
79	CCPM: Complexity of Method	4.0	3.11	6.0	3.19	-2.0	0.823	0.1985

[1] Mann-Whitney Test is conducted for 95% confidence and p-value is adjusted for ties.

Table 5-22

Chi-squared analysis results for all CCPM implementations combined (multi-project and single-project)

ID	Factor	Presence of Factor	Low Success (<7) Count Expected Count	High Success (>6) Count Expected Count	Chi-Squared p-value
76	CCPM: Focused Work	Low (<7)	13 10.00	7 10.00	0.126
		High (>6)	6 33.00	17 33.00	
71	CCPM: Buffer Duration Method	Low (<7)	10 6.98	10 13.02	0.105
		High (>6)	20 23.02	46 42.98	
25	Feature: Clear Scope	Low (<7)	6 3.26	14 16.74	**0.058****
		High (>6)	8 10.74	58 55.26	

**Null hypothesis rejected for higher alpha level of 0.10. This means at an alpha level of 0.10 there is a dependent relationship between the factor and the success of the implementation.

From Table 5-20 above, the statistically significant factors (alpha level of 0.05 and 0.10) included six goal factors, six CCPM features, three change management factors, and two CCPM-specific factors. There are not any combined data results for statistically significant factors in the pre-existing conditions category; however, from the categorical question analysis, the number of tasks per project was dependent with CCPM success at an alpha level of 0.10 for combined data. All factors identified for the combined data were positively associated with successful CCPM implementations. The high concentration of goal factors and CCPM feature factors suggests that with greater understanding of CCPM and higher implementation levels of CCPM features, the CCPM implementation is more likely to be successful. Table 5-23 below summarizes the results between the influential factors identified for single-project implementations, multi-project implementations, and the two implementation types combined.

Table 5-23

Summary of factors (ordered by magnitude of difference between medians for high-success and low-success implementations) associated with CCPM implementation success rate

ID	Factor	Multi-Project Analysis	Single-Project Analysis	Combined^ Analysis
C	Pre-existing: Number of Tasks per Project		**– ***	**– ****
5	Pre-existing: PM Practices	**+2.5****		
7	Pre-existing: Critical Path	**+1.5****		
22	Goal: New Product Introduction		**+ 6.5***	**+ 5.0***
14	Goal: Less Scope Changes		**+ 6.0***	
11	Goal: Increase Throughput		**+ 4.5***	
9	Goal: Try it Out		**+ 4.0***	
19	Goal: Project Completion Percentage	**+ 2.5***	**+ 3.5***	**+ 3.5***
15	Goal: Less Cost Increases		**+ 3.5***	
24	Goal: Financial Benefits		**+ 3.0****	**+ 0.5****
18	Goal: Reduce Stress		**+ 3.0***	
13	Goal: Quality		**+ 2.5***	**+ 2.0***
17	Goal: Manage Resources			**+ 1.5***
12	Goal: On-Time Delivery			**+ 0.5***
43	Feature: Supplier/Contractor Integration		**+ 5.5***	
27	Feature: 50% Duration Estimates		**+ 4.0***	
37	Feature: Buffer Recovery Actions	**+ 3.5***	**+ 3.5****	**+ 3.5***
31	Feature: Resource Buffers		**+ 3.5***	**+ 4.0***
26	Feature: Tasks Defined		**+ 3.0***	**+ 2.5****
28	Feature: Baseline Critical Chain		**+ 2.5***	
38	Feature: Remaining Task Duration Reporting		**+ 2.0***	
40	Feature: Minimized Multitasking		**+ 2.0**	
25	Feature: Clear Scope	**+ 3.5***		**+ 1.0****
39	Feature: Rescheduling as Exception	**+ 3.5***		
33	Feature: Drum Buffers	**– 3.0****		
41	Feature: Priority Task List	**+ 2.5****	**+ 1.5****	
42	Feature: Road Runner Mentality		**+ 1.0****	**+ 2.0***
36	Feature: Buffer Management			**+ 1.0****

C references a chi-squared analysis for categorical questions.

^Combined analysis indicates multi-project and single-project implementations were analyzed together to show factors that similarly influence both types of implementations. Combined analysis was justified for 44 of the 82 ordinal-scaled question responses (see discussion for more detail).

+ Indicates the factor has a positive influence.

– Indicates the factor has a negative influence.

***** Indicates the factor uses an alpha level of 0.05 for hypothesis testing (Mann-Whitney or chi-squared if needed).

****** Indicates the factor uses an alpha level of 0.10 for hypothesis testing (Mann-Whitney or chi-squared if needed).

Table 5-23
Summary of factors (ordered by magnitude of difference between medians for high-success and low-success implementations) associated with CCPM implementation success rate

ID	Factor	Multi-Project Analysis	Single-Project Analysis	Combined^ Analysis
54	Change: Stakeholder Involvement		**+ 6.5***	**+ 3.5***
59	Change: Training Adequate		**+ 5.5***	
63	Change: Incremental Measurements		**+ 5.0***	
44	Change: Buy-In Established		**+ 4.5***	
51	Change: Vision		**+ 4.5***	
57	Change: Role Changes/ Integration		**+ 4.5***	
67	Change: Customization to Build Ownership		**+ 3.5****	
49	Change: Champion Participation		**+ 3.5***	
55	Change: Software Functionality		**+ 3.5***	
66	Change: Performance Management Reinforcement		**+ 3.0****	**+ 1.5***
68	Change: Planned as Project		**+ 3.0****	
65	Change: Quick Wins	**+ 2.5****	**+ 3.0***	
45	Change: Buy-In Maintained		**+ 3.0***	**+ 1.5***
48	Change: Champion		**+ 2.5****	
64	Change: At End Measurements		**+ 2.0****	
46	Change: Resistance	**– 2.5****		
52	Change: Communication	**– 1.5****		
69	CCPM: Desire for Standard	**+ 4.5****	**+ 5.5***	**+ 4.5***
76	CCPM: Focused Work		**+ 4.0***	
75	CCPM: Management Interruptions		**– 2.5****	
78	CCPM: Delayed Starts		**– 2.5***	
70	CCPM: Task Duration Method	**+ 4.0***	**+ 2.0****	**+ 1.5***
79	CCPM: Complexity of Method		**– 2.0***	

^Combined analysis indicates multi-project and single-project implementations were analyzed together to show factors that similarly influence both types of implementations. Combined analysis was justified for 44 of the 82 ordinal-scaled question responses (see discussion for more detail).
+ Indicates the factor has a positive influence.
– Indicates the factor has a negative influence.
***** Indicates the factor uses an alpha level of 0.05 for hypothesis testing (Mann-Whitney or chi-squared if needed)
****** Indicates the factor uses a higher alpha level of 0.10 for hypothesis testing (Mann-Whitney or chi-squared if needed)

From Table 5-23 above, single-project implementations have the greatest number of factors in which the difference between the medians for high-success and low-success implementation experiences are statistically significant. Differences between medians also have the highest magnitudes for single-project implementations. This confirms the discussion above that the sample of single-project high successes and low successes were very different in how the

CCPM implementations were conducted. Multi-project implementations had more similarities between high successes and low successes, so the few factors identified (13) are significant in their ability to influence the outcome of multi-project CCPM implementations that are already focusing on implementing CCPM features and following change management best practices.

Combining multi-project and single-project data revealed factors that can be considered CCPM success factors regardless of implementation type. Three factors that had not been previously revealed through single-project or multi-project implementations include the goal to better manage resources, the goal to increase on-time delivery, and using buffer management as a feature of CCPM. There are also a few consistent factors that are present in multi-project implementations, single-project implementations, and also statistically significant when using the combined (multi-project and single-project) data for analysis. This includes the following: having a goal of increasing the project completion percentage, using buffer recovery actions as a CCPM feature, having the desire for a CCPM standard, and satisfaction with the method used for task duration estimates. Across all types of CCPM implementations, these four factors are the most significant factors for CCPM implementation success.

Perception of Most Influential Factors

There was an optional question that was included in the survey to gauge participants' perceptions about which factors contribute most to CCPM implementation success and failure. The perceptions of each participant were separated based on the participant's experience with multi-project or single project implementations. Table 5-24 and Table 5-25 show the top five factors as identified by survey participants for each type of implementation. Additionally, the table gives the average magnitude from the survey analysis for the condensed factor if the perceived top-five factor was validated. People with experience in single-project implementations are better able to identify factors that actually influence CCPM implementation success and failure over people with multi-project implementation experiences. Survey analysis validated three of the top five for both success and failure for single-project implementers. For multi-project implementers, survey analysis only validated one of the top five for both success and failure. The ability to better identify factors that influence success might be impacted by the proportion of participants with high success versus low success. People with low-success experiences may be able to better pinpoint what caused a low-success outcome, and when more people have low success, the group as a whole can better identify influential factors (as either contributors or detriments to success). For multi-project implementations there were only eight low successes in comparison to 43 high successes, which may have contributed to the mismatch between perceived influential factors and actual influential factors.

Leadership support is perceived to be the most important factor for both multi-project and single-project implementations. The survey analysis does not identify this as an influential factor because the eight low-success implementations all had strong leadership support in the implementation. A larger sample of low-success multi-project implementations survey responses would need to be collected to identify if leadership support is truly consistent amongst both high-success and low-success implementations. A larger sample of participants with low-success implementation experiences may also help the group as a whole better identify the most influential factors.

Table 5-24

Survey participants' perception of top five most important factors influencing CCPM implementation success rate by implementation type

Condensed Factor	Multi-project[1] (count)[2]	Validated? (average median difference)[3]	Single-project[1] (count)[2]	Validated? (average median difference)[3]	Combined[1] (count)[2]
Change Factor: Leadership Support	30	NO	17	YES (+3)	47
Change Factor: Buy-In and/or Organizational Support	22	NO	12	YES (+4)	34
Pre-existing: Project Management Practices	17	YES (+2.5)	11	NO	28
Pre-existing: Project Focus (cost, time, scope, or quality)			13	NO	20
Primary Goal: Speed up Projects			9	YES (+5.5*)	19
CCPM Factor: Multitasking Eliminated	15	NO			19
Change Factor: Role Changes / Integration	12	NO			

[1] Frequencies for participant responses were separated based on the participant's implementation experience (multi-project, single-project, or the total combined).
[2] Count refers to the frequency of the factor perceived to be a significant factor by survey participants.
[3] To validate with a "yes," the survey analysis showed there was a difference between the median values for high-success and low-success implementations. The average (since some factors were condensed) median difference is reported with a positive sign indicating that increased presence of the factor corresponds with higher successes.
*Speed up projects in terms of the goals for increased throughput and new product introduction.

As shown in Table 5-25 below, the lack of a critical chain standard was perceived to be one of the top five detriments to the CCPM implementation success for single-project implementations. The survey unsuccessfully represented the impact due to the lack of a critical chain standard and instead measured the desire for a critical chain standard. Future studies will need to include the lack of a standard as a factor to determine the actual impact, unless a standard were constructed before a new study is conducted.

Table 5-25

Survey participants' perception of top five most detrimental factors influencing CCPM implementation success rate by implementation type

Condensed Factor	Multi-project[1] (count)[2]	Validated? (average median difference)[3]	Single-project[1] (count)[2]	Validated? (average median difference)[3]	Combined[1] (count)[2]
Change Factor: Lack of Leadership Support	21	NO	12	YES (-3.0*)	33
Change Factor: Resistance	19	YES (-2.5)	13	NO	32
CCPM Factor: Multitasking Not Eliminated	15	NO			
Change Factor: Lack of Urgency	15	NO			
CCPM Factor: Non-Project Work	14	NO	12	NO	26
CCPM Factor: Lack of Critical Chain Standard			12	NO (+5.5**)	
Change Factor: Lack of Buy-In and/or Organizational Support	14	NO	11	YES (-3.0)	25
Pre-existing: Use of Scheduling Techniques			11	NO	23
CCPM Factor: Management Interruptions	14	NO			

[1] Frequencies for participant responses were separated based on the participant's implementation experience (multi-project, single-project, or the total combined).
[2] Count refers to the frequency of the factor perceived to be a significant factor by survey participants.
[3] To validate with a "yes," the survey analysis showed there was a difference between the median values for high-success and low-success implementations. The average (since some factors were condensed) median difference is reported with a negative sign indicating that decreased presence of the factor corresponds with higher successes.
* Positive relationship for presence of factor was reversed to show impact for lack of factor.
** Survey did not adequately address lack of standard and instead assessed desire for a standard. Implementations with low success had a lower desire for standard in comparison to high success implementations.

CHAPTER 6

INTERVIEW FINDINGS

Interviews were conducted on a volunteer basis to identify additional factors to supplement those identified in the survey. To solicit participation for the interviews, the researcher followed leads from thesis committee member suggestions, was contacted directly via email by thesis committee members' professional contacts, or was contacted directly via email by willing survey participants. Of fifteen potential interview participants, ten completed the interview process. Of the five that did not participate, only one responded to follow-up emails and declined for company confidentiality reasons. The consent form had information about how the survey was going to be administered, which may have discouraged potential interview participants (the consent form is attached in Appendix D). This may be due to one of the following reasons: there were no direct questions and instead the interview required the participant to explain his or her CCPM implementation experience in detail which might not the preferred interview style, the interview and follow-up survey time was estimated to take one hour and twenty minutes which might be considered too much time, and/or the interviews were conducted via a recorded phone conversations which might be intimidating for some people. The four other potential participants may have failed to follow-up for these or other reasons.

Within the ten interviews that were conducted (interviewees A through J in Table 6-1 below), thirteen separate implementation events were discussed. Three interview participants shared, in a comparative fashion, two different implementation approaches that the same company used (identified using superscripts [1] and [2] in Table 6-1 below). Overall, three interviewees shared low-success implementation experiences, one interviewee shared a moderately successful implementation experience, and the rest were high-success implementations. The moderately successful implementation, interviewee J, was identified as such since there were not adequate baseline measurements to measure the incremental and at-end achievements from the CCPM implementation. For interviewee J, there were indications that the CCPM methodology had a positive impact, but a belief of dissatisfaction that the benefits could not be realized through measurements directly impacted the belief of overwhelming success.

The interviews, once completed, were transcribed and then analyzed in comparison to the factors identified in the survey. Interviewees mentioned references to factors based on their importance to the implementation, negative impact on the implementation, absence that impacted the implementation, or mentioned a factor without stating either the factor’s negative or positive impact on the CCPM implementation outcome. Table 6-1 below shows the factors identified in the interview and are coded as mentioned (M) for factors that were identified without a positive or negative impact, important (I) for factors that the interviewee felt positively impacted the implementation outcome, negative impact (NI) for factors that the interviewee felt negatively impacted the implementation outcome, and lack of factor (L) for when the interviewee felt that the absence of a factor had an impact on the implementation outcome. The interviews were analyzed and interpreted solely by the researcher. To minimize interpretation errors, a tracked survey (identical to the main survey) was used as a comparative tool to determine if there was agreement between identified factors in the interview and how the interview participants rated the presence of the factors when completing the survey. The results presented in Table 6-1 below correspond to results from each interviewee’s individual survey.

Table 6-1

Interview analysis for CCPM implementation success factors

INTERVIEWEES	A	B^1	B^2	C^1	C^2	D	E	F	G	H	I^1	I^2	J	Totals
SUCCESS: Low (L), Moderate (M), High (H)	H	L	H	L	H	H	H	H	H	L	H	H	M	13
Project Type: Multi-Project (MP), Single-Project (SP)	MP	MP	MP	MP	MP	SP	MP	MP	MP	SP	MP	MP	MP	13
Industry: Software (S), Production (P), Engineering (E), Pharmaceutical (Ph), Aerospace (A), Communication (C)	S	P	P	E	E	E	A	C	E	P	Ph	Ph	Ph	13
KEY for Identified Factors: Mentioned (M), Important (I), Negative Impact (NI), Lack of Factor (L)														
Pre-Existing: Project Management Office	M								M	M			M	4
Pre-Existing: Project Management Practices				L	L		L		L	L				5
Pre-Existing: Network-Based Scheduling	M			L	L								L	4
Pre-Existing: Critical Path Method		M	M	L	L	M				M				6
Pre-Existing: Number of Project Tasks												M		1
Pre-Existing: Number of People in the Organization													M	1
Pre-Existing (NEW): Number of Projects				M	M								M	3
Pre-Existing (NEW): Project Resources also Responsible for Short-Term Requests							M		M	M				3
Pre-Existing (NEW): Leader with Previous Experience							M		M	M				3
Goal: Increase On-Time Delivery		M	M	M	M	M	M				M			7
Goal: Complete Project(s) Faster		M	M				M					M	M	5
Goal: Increase Throughput													M	1
Goal: Increase Chance of Project Completion(s)				M	M									2
Goal: Ability to Better Prioritize							M							1
Goal: Speed-to-Market												M		1
Goal: Financially Contribute to Bottom Line												M		1
Feature: Clear Task Definitions													I	1
Feature: Baseline Critical Chain	M												I	2
Feature: Reduced Task Durations by 50%	I					L				L				3
Feature: Project Buffer	M					M								2
Feature: Buffer Management to Monitor and Control	M					I	I				I	I	I	6
Feature: Buffer Recovery Actions	I					I	I							3

Table 6-1

Interview analysis for CCPM implementation success factors

INTERVIEWEES	A	B^1	B^2	C^1	C^2	D	E	F	G	H	I^1	I^2	J	Totals
SUCCESS: Low (L), Moderate (M), High (H)	H	L	H	L	H	H	H	H	H	L	H	H	M	13
Project Type: Multi-Project (MP), Single-Project (SP)	MP	MP	MP	MP	MP	SP	MP	MP	MP	SP	MP	MP	MP	13
Industry: Software (S), Production (P), Engineering (E), Pharmaceutical (Ph), Aerospace (A), Communication (C)	S	P	P	E	E	E	A	C	E	P	Ph	Ph	Ph	13
KEY for Identified Factors: Mentioned (M), Important (I), Negative Impact (NI), Lack of Factor (L)														
Feature: Minimize Multitasking	M				I									2
Feature: Priorities Understood				L	I		I			L		I		5
Feature: Stagger Projects in Multi-Project Environment	I			M	I		I						M	5
Feature (NEW): Include All Projects in Implementation													I	1
Feature (NEW): Reduce Number of Working Projects	I			L	I		I						M	5
Change: Buy-In Established	I*			M	M	M	I		I			I	I	8
Change: Champion from Top Management	I	M	I	L	I		I	I	I	M	I	I	I	12
Change: Champion Participation Throughout	I	M	I	L			L	I	I				L	8
Change: Vision		M												1
Change: Urgency									I					1
Change: Communication									I	L			L	3
Change: External Consultant	I	M		M	M		M		I				I	7
Change: Role and Responsibility Changes	I^						I^		I^		M^		I^	5
Change: Customization to Build Ownership			I			I	I		I					4
Change: Change Agents					I								I	2
Change: Resistance		NI*		NI*					M	NI*	NI*	L*		6
Change: Designed for Quick-Wins	I	M									M		M	4
Change: Incremental Measurements	I								I				L	3
Change: At-End Measurements	M				M			M			M		L	5
Change: Performance Management Reinforces Behaviors	I	M	I	L	I			I	I	L	L	I		10
Change: Adequate Training		M					I				I		I	4
Change: Training on Project Management Basics				I	I		I		I					4

Table 6-1

Interview analysis for CCPM implementation success factors

INTERVIEWEES	A	B[1]	B[2]	C[1]	C[2]	D	E	F	G	H	I[1]	I[2]	J	Totals
SUCCESS: Low (L), Moderate (M), High (H)	H	L	H	L	H	H	H	H	H	L	H	H	M	13
Project Type: Multi-Project (MP), Single-Project (SP)	MP	MP	MP	MP	MP	SP	MP	MP	MP	SP	MP	MP	MP	13
Industry: Software (S), Production (P), Engineering (E), Pharmaceutical (Ph), Aerospace (A), Communication (C)	S	P	P	E	E	E	A	C	E	P	Ph	Ph	Ph	13
KEY for Identified Factors: Mentioned (M), Important (I), Negative Impact (NI), Lack of Factor (L)														
Change: Practical Training							L							1
Change: Planned as a Project							I						I	2
Change: CCPM Software Functionality					I									1
Change (NEW): Initial Workshop		M		M						M			M	4
Change (NEW): Significant Financial Investment					I					L				2
CCPM: Frequent Rescheduling (Re-Prioritization)		NI								NI				2
CCPM: Non-Project Work				NI	NI	M	NI			NI			M	6
CCPM: Multitasking Eliminated				L		L	L	I		L			L	6
CCPM: Used with Lean methods					I								M	2
CCPM (NEW): Initial Analysis to Determine Constraint	I								I		I			3
CCPM (NEW): Buy-in for Theory of Constraint (TOC) Philosophy (regardless of CCPM)	I		I				I		I				I	5
CCPM (NEW): Used with Agile	I		I											2
CCPM (NEW): Predefined Action Steps for Specific Situations	I						L		I					3
CCPM (NEW): Reorganization of Project Structure							I	L	I					3
CCPM (NEW): Focus on Continuous Improvement							M		M				I	3
CCPM (NEW): Use of TOC Strategy and Tactics Tree (Published by Goldratt Consulting, Inc.)													I	1

[1] and [2] represent separate CCPM implementation approaches for the same organization.

* represents the specific mention of middle management in relation to the identified factor.

^ represents the specific mention of the formation of a cross-functional or steering team for the implementation.

Along with matching the identified factors with factors from the survey, the main purpose of the interviews was to determine if there were additional factors that can potentially impact CCPM implementation success that were not included in the survey. The interview process was successful in identifying factors that could potentially impact critical chain success in four of the five groupings of factors—pre-existing conditions, features, change factors, and CCPM-specific factors. The fourteen new factors are identified in Table 6-1 above and are highlighted with "(NEW)" behind the factor in addition to having a green background. Of the fourteen new factors, twelve factors were common amongst at least two and up to five interviewees. With the identification of new factors through the interview process, the assumption that the survey was comprehensive is false. The influences of factors as indentified by the survey are not affected by showing this assumption is false. However, the survey cannot be considered a comprehensive assessment and analysis of the newly-identified factors will require further research.

The identification of new factors is also contingent upon the researcher's interpretation of the interviews. The factors most susceptible to error in this process were factors mentioned (M in Table 6-1) but not necessarily identified as being significant to the implementation outcome. These include the following pre-existing conditions: the number of projects in the organization, project resources also being responsible for short-term requests, and having a leader with previous experience with CCPM. One change factor was also included, holding an initial workshop as one of the first implementation steps. These new factors are significant enough to include since more than one interviewee discussed the factor without being prompted, but no other conclusions can be made about their potential impact without further research.

Other new factors have less probability of interpretation error because the interviewees identified the factors as being important. For CCPM features, inclusion of reducing the amount of current projects being worked on, also referred to as reducing work-in-process (WIP), was identified by interviewees (A, C, and E in Table 6-1) as separate from staggering projects in a multi-project environment. Staggering the introduction of projects has the effect of reducing the amount of projects that resources are working on at one time; however, the interviewees mentioned the processes of “freezing” projects to reduce the number of projects in the system before attempting to stagger the projects. Additionally, for CCPM features, ensuring all projects are included in multi-project implementations was identified as a new factor.

There were also two new factors identified in relation to change management. Conducting an initial workshop to gather the team, train, and discuss the implementation plan was mentioned multiple times by interviewees (B, C, H, and J in Table 6-1) without necessarily being identified as important. The other factor, significant financial investment, is related to buy-in and commitment to the implementation. In the case of interviewee C[2]’s experience, because of the decision to make a significant investment in CCPM software, “management was committed to show some result” (personal communication, April 17, 2012). This contributed to a more successful outcome in the second CCPM implementation attempt using a new approach (personal communication, April 17, 2012). Alternately, in the experience described by interviewee H, there was a reluctance to spend any money on the implementation effort and use all in-house resources; this contributed to a failed outcome (personal communication, May 8, 2012). The level of financial investment in the change may be a factor to consider in future research both in CCPM implementation as well as broader research in change management.

For change management, as highlighted by the interviews, the role that middle management plays in the change initiative. Management resistance from middle-level managers seemed to be a consistent theme as a negative influence across several interviews (B, C, H, and I in Table 6-1). Interviewee A also noted that gaining the buy-in of middle-management was essential in the success of the implementation in its ability to withstand a turnover of the CCPM champion during the implementation effort (personal communication, April 17, 2012). On this same topic, Prosci's newest annual study *Best Practices in Change Management – 2012 Edition* for the first time identifies "engagement with and support from middle management" as one of the top contributors to overall change management success (Prosci, n.d.). Indentifying the role that middle management plays in a change initiative is important for future research in CCPM implementations as well as future change management research (Creasey, 2012).

A second refinement of factors is the role that steering teams or cross-functional teams play in the change initiative. As seen in Table 6-1, all five interviewees that mentioned the factor related to role and responsibility changes mentioned the formation of a steering-team or a cross-functional team to oversee the CCPM implementation effort. Interviewee J noted that "the core team was important to get buy-in deeper into the organization" while other interviewees noted that the team can work together to customize the CCPM implementation to build ownership (Interview E, 2012; Interview G, 2012). From the interviews, team structure appears to play an important role in the change effort (as discussed in the literature review) and may also be correlated to other factors, such as establishing or maintaining buy-in for the CCPM effort.

The final grouping that saw the greatest number of newly-identified factors was CCPM-specific factors. This is understandable due to the lack of structured research around CCPM implementations, as demonstrated in the literature review. The new factors identified include the following: completing an initial analysis to determine the system constraint of the organization before initiating the CCPM implementation effort, gaining buy-in for the Theory of Constraint (TOC) philosophy regardless of the CCPM process, using CCPM in conjunction with Agile methods, using predefined action steps to assist CCPM practitioners in specific situations (such as what to do when the buffer reaches the red zone or what does a project team member do when they are being asked to multitask by someone above them), reorganizing the project structure within the organizational structure, focusing on continuous improvement as part of the CCPM process, and using the TOC Strategy and Tactics (S&T) Tree (published by Goldratt Consulting, Inc.) as a roadmap for a CCPM implementation. All of these factors identified as important by one or more interviewees deserve additional attention in future CCPM implementation research.

One of the newly-identified factors was deemed important by five of the ten interviewees: gaining buy-in for the TOC philosophy regardless of the CCPM process. The most significant demonstration of this factor's influence in a successful CCPM implementation was given by interviewee B. Interviewee B described a low-success CCPM implementation due to change resistance in comparison to a high-success CCPM implementation attempt in which the new leader halted the CCPM implementation effort and continued with a successful "CCPM implementation" by espousing personal virtues that were in line with the TOC philosophy (personal communication, May 15, 2012). In this case, the "CCPM implementation" was no longer being viewed as a change initiative and was able to progress using the principles of the TOC philosophy, but without labeling as such, and hence avoiding a strong cultural resistance to change. Other interviewees also highlighted that project managers and practitioners participating in the CCPM implementation needed to understand and embrace CCPM in line with the underlying principles of the TOC philosophy.

As part of the interview, some interviewees mentioned factors that are important to ensure that CCPM can be sustained. This included such factors as establishing deep buy-in throughout the organization so that CCPM will withstand management changes (Interviewee A, personal communication, April 17, 2012), having an internal position/role established to ensure that continuous improvement methodologies are maintained in conjunction with the use of CCPM (Interviewee E, personal communication, April 20, 2012), keeping a standing committee that has a feedback mechanism in place (such as audits) to continually focus on improving the CCPM process (Interviewee G, personal communication, April 13, 2012), setting up a process to train new employees/managers entering the organization about CCPM and the reasons for its use (Interviewee I, personal communication, April 12, 2012), and reorganizing the organizational structure to ensure that the CCPM process can withstand management changes (Interviewee F, personal communication, May 8, 2012). Interviewee E and Interviewee G both mentioned reorganization as a precursor to the CCPM implementation, also identified as a new factor in Table 6-1. This reorganization was meant to ensure that the long-term projects were separated from the short-term, daily requests so that project resources were not forced to multitask. Taking away one of the root causes of multitasking within an organization (the goal of this type of reorganization) was essential in ensuring a successful CCPM implementation, where resources would not be required to split their time between short-term requests and long-term projects. This is also related to one of the identified pre-existing condition factors that can potentially affect the CCPM implementation outcome, the presence of need for project resources to also be responsible for short-term requests.

Interviewee F further emphasized reorganization at the highest levels of the organizational structure to remedy the root cause of multitasking—conflicting priorities given by upper management in the silo structure (personal communication, May 8, 2012). Once focus is diverted away from the CCPM effort (a leadership change or other distractions), multitasking will return because the organizational structure inherently causes multitasking (Interviewee F, personal communication, May 8, 2012). Interviewee F described a missing role at the top of an organization, someone over all functional silo leaders, to focus on internal operations on a daily/weekly basis without being distracted by strategic decisions (personal communication, May 8, 2012). Currently, in many organizations, the only person with the authority over all functional silo leads is the Chief Executive Officer (CEO), whose primary role is strategic instead of operational (Interviewee F, personal communication, May 8, 2012). Without a leader to focus on operational decisions and priorities of the overall company, the leaders of each silo within the company are left to make decisions as a collective group (Interviewee F, personal communication, May 8, 2012). This creates a problem, as Interviewee F pointed out, because "nobody is in charge…and nobody is willing to take on the risk [of determining what the highest priority projects are]" (personal communication, May 8, 2012). This leads to multitasking being engrained in an organization as a consequence of the organizational structure, often to such an extent that even when multitasking is temporarily removed through successful CCPM implementations, it returns with the loss of focus and/or management turnover (Interviewee F, personal communication, May 8, 2012).

The literature review highlighted the potential impact of an upper management or senior-level leader to champion a change initiative, while the survey results show that a champion from upper/senior management influences CCPM implementation success for single-project implementations, and the leader/champion was important or mentioned in twelve of the thirteen CCPM implementation experiences shared by the interviewees as shown in Table 6-1 above. To further demonstrate the impact of the CCPM champion, many of the interviewees mentioned that once the champion of the CCPM effort diverted attention away from the implementation, the CCPM implementation effort halted or noticeably slowed down (Interviewee A, 2012;

Interviewee E, 2012; Interviewee G, 2012; Interviewee H, 2012; Interviewee I, 2012). Interviewee F further noted that even with the most successful implementations, once the CCPM champion gets distracted by other initiatives or leaves the company, people quickly revert back to multitasking and all the benefits of CCPM fade (Interviewee F, personal communication, May 8, 2012). Interviewee F described this type of failure as a CCPM sustainment failure (as opposed to a CCPM implementation or deployment failure) and from personal experience has witnessed that all CCPM implementations are doomed to sustainment failure (personal communication, May 8, 2012). Interviewee I[1] also described a specific example of this type of sustainment failure after a successful implementation, where the company turned its focus away from the CCPM effort to focus on reducing the workforce through layoffs (personal communication, April 12, 2012). Further research is needed to determine if the sustainment failure of CCPM can be eliminated or reduced by changing the organizational structure, as suggested by Interviewee F, to include a senior-level leader that focuses internally on the organization, providing operational direction on a daily/weekly basis by making decisions about priorities for the entire organization.

CHAPTER 7

CONCLUSIONS

The combined methodology using the survey and interviews effectively identified factors that are important to the success of CCPM implementation.

Survey Findings

The analysis of the categorical questions revealed that for the multi-project versus single-project survey responses completed, multi-project CCPM implementations were more likely to be successful. Single-project implementations, especially smaller projects, may be perceived to need less investment (time and effort) than is actually needed. By not investing the needed time and effort, single-project implementations may be less successful than multi-project implementations that require a bigger overall investment of time and effort. Additionally, the findings indicated that single-project and multi-project implementations needed to be analyzed separately for the ordinal-scaled question analyses.

In response to the research questions, all five categories (pre-existing conditions, CCPM goals established, CCPM features implemented, change management factors, and CCPM-specific factors) have factors in which there is a statistically significant difference between high-success and low-success projects. Table 7-1 shows the differences for each significant factor in multi-project implementations in order of absolute magnitude of the differences between median values for high-success and low-success implementations. Similarly, Table 7-2 and Table 7-3 show the same information for single-project and combined multi- and single-project implementations, respectively.

Table 7-1

Factors with statistically-significant differences between medians for high-success and low-success multi-project CCPM implementations

ID	Factor Description	Factor Group	Difference between Medians	TEST[1]	TEST p-value
69	Desire for Standard	CCPM	+4.5	MW	**0.0875****
70	Task Duration Method	CCPM	+4.0	MW	**0.0059***
39	Rescheduling as Exception	Feature	+3.5	MW	**0.0092***
25	Clear Scope	Feature	+3.5	MW	**0.0111***
37	Buffer Recovery Actions	Feature	+3.5	MW	**0.0339***
33	Drum Buffers	Feature	-3.0	MW	**0.0734****
19	Project Completion Percentage	Goal	+2.5	MW	**0.0311***
41	Priority Task List	Feature	+2.5	**CS**	**0.065****
65	Quick Wins	Change	+2.5	MW	**0.0786****
46	Resistance	Change	-2.5	MW	**0.0827****
5	PM Practices	Pre-existing	+2.5	MW	**0.0894****
7	Critical Path Method	Pre-existing	+1.5	MW	**0.0854****
52	Communication	Change	-1.5	MW	**0.0968****

[1] MW refers to Mann-Whitney Test and CS refers to chi-squared analysis.
* Represents rejection of null hypothesis based on alpha level of 0.05.
** Represents rejection of null hypothesis based on alpha level of 0.10.

For multi-project implementations (as shown above in Table 7-1), the most significant factors are specifically related to CCPM and the features implemented. The implementers participating in high-success multi-project implementations are satisfied with the task duration method used (the standard 50% task duration method), reschedule infrequently, have clear scope for projects within the CCPM system, plan buffer recovery actions and take actions when needed, and do not use drum buffers. For single-project implementations (as shown in Table 7-2 below), the factors with the highest magnitudes fall under goals for CCPM, CCPM features implemented, and change management factors. High-success single-project CCPM implementations are being conducted on larger projects (with more tasks), are focused on understanding the potential benefits of CCPM, are implementing the necessary features, and are committed to using change management techniques.

Table 7-2

Factors with statistically significant differences between medians for high-success and low-success single-project CCPM implementations

ID	Factor Description	Factor Group	Difference between Medians	TEST[1]	TEST p-value
22	New Product Introduction	Goal	+6.5	MW	**0.0198***
54	Stakeholder Involvement	Change	+6.5	MW	**0.0091***
14	Less Scope Changes	Goal	+6.0	MW	**0.0260***
43	Supplier/ Contractor Integration	Feature	+5.5	MW	**0.0139***
59	Training Adequate	Change	+5.5	MW	**0.0044***
69	Desire for Standard	CCPM	+5.5	MW	**0.0027***
63	Incremental Measurements	Change	+5.0	MW	**0.0061***
11	Increase Throughput	Goal	+4.5	MW	**0.0171***
44	Buy-In Established	Change	+4.5	MW	**0.0263***
51	Vision	Change	+4.5	MW	**0.0125***
57	Role Changes/ Integration	Change	+4.5	MW	**0.0464***
9	Try it Out	Goal	+4.0	MW	**0.0256***
27	50% Duration Estimates	Feature	+4.0	MW	**0.0300***
76	Focused Work	CCPM	+4.0	**CS**	**0.024***
15	Less Cost Increases	Goal	+3.5	MW	**0.0074***
19	Project Completion Percentage	Goal	+3.5	MW	**0.0309***
31	Resource Buffers	Feature	+3.5	MW	**0.0093***
37	Buffer Recovery Actions	Feature	+3.5	MW	**0.0605****
49	Champion Participation	Change	+3.5	MW	**0.0996****
55	Software Functionality	Change	+3.5	MW	**0.0401***
67	Customization to Build Ownership	Change	+3.5	MW	**0.0502****
18	Reduce Stress	Goal	+3.0	MW	**0.0011***
24	Financial Benefits	Goal	+3.0	MW	**0.0806****
26	Tasks Defined	Feature	+3.0	**CS**	**0.040***
45	Buy-In Maintained	Change	+3.0	MW	**0.0104***
65	Quick Wins	Change	+3.0	MW	**0.0357***
66	Performance Management Reinforcement	Change	+3.0	MW	**0.0652****
68	Planned as Project	Change	+3.0	MW	**0.0894****
13	Quality	Goal	+2.5	MW	**0.0440***
28	Baseline Critical Chain	Feature	+2.5	MW	**0.0243***
48	Champion	Change	+2.5	MW	**0.0991****
75	Management Interruptions	CCPM	-2.5	MW	**0.0974****
78	Delayed Starts	CCPM	-2.5	MW	**0.0441***
38	Remaining Task Duration Reporting	Feature	+2.0	**CS**	**0.043***
40	Minimized Multitasking	Feature	+2.0	MW	**0.0240***
64	At End Measurements	Change	+2.0	**CS**	**0.061****
70	Task Duration Method	CCPM	+2.0	MW	**0.0760****
79	Complexity of Method	CCPM	-2.0	MW	**0.0499***
41	Priority Task List	Feature	+1.5	MW	**0.0602****
42	Road Runner Mentality	Feature	+1.0	MW	**0.0739****
C	Number of Tasks per Project	Pre-existing	N/A	CS	**0.010***

[1] MW refers to Mann-Whitney Test and CS refers to chi-squared analysis.

* Represents rejection of null hypothesis based on alpha level of 0.05.

** Represents rejection of null hypothesis based on alpha level of 0.10.

Table 7-3

Factors with statistically-significant differences between medians for high-success and low-success combined multi- and single-project CCPM implementations

ID	Factor Description	Factor Group	Difference between Medians	TEST[1]	TEST p-value
22	New Product Introduction	Goal	+5.0	MW	**0.0148***
69	Desire for Standard	CCPM	+4.5	MW	**0.0007***
31	Resource Buffers	Feature	+4.0	MW	**0.0019***
19	Project Completion Percentage	Goal	+3.5	MW	**0.0016***
37	Buffer Recovery Actions	Feature	+3.5	MW	**0.0016***
54	Stakeholder Involvement	Change	+3.5	MW	**0.0357***
26	Feature: Tasks Defined	Feature	+2.5	MW	**0.0738****
13	Quality	Goal	+2.0	MW	**0.0180***
42	Road Runner Mentality	Feature	+2.0	MW	**0.0086***
17	Manage Resources	Goal	+1.5	MW	**0.0266***
45	Buy-In Maintained	Change	+1.5	MW	**0.0499***
66	Performance Management Reinforcement	Change	+1.5	MW	**0.0450***
70	Task Duration Method	CCPM	+1.5	MW	**0.0037***
25	Clear Scope	Feature	+1.0	**CS**	**0.058****
36	Buffer Management	Feature	+1.0	MW	**0.0904****
12	On-Time Delivery	Goal	+0.5	MW	**0.0452***
24	Financial Benefits	Goal	+0.5	MW	**0.0974****
C	Number of Tasks per Project	Pre-Existing	N/A	CS	**0.070****

[1] MW refers to Mann-Whitney Test and CS refers to chi-squared analysis.
* Represents rejection of null hypothesis based on alpha level of 0.05.
** Represents rejection of null hypothesis based on alpha level of 0.10.

For multi- and single-project combined analysis (as shown above in Table 7-3), significant factors include six goals, six features, three change factors, two CCPM-specific factors, and one pre-existing condition. Table 7-3 highlights factors that are significant to the success of CCPM regardless of implementation type.

Finally, analysis was conducted for the optional question included in the survey about the perception of most influential factors (from a condensed factor list) in achieving high-success or low-success implementation outcomes. There is a greater ability to perceive which factors can influence CCPM success when there is a higher proportion of participation from implementers with low-success experiences. Even with more participation from individual with low-success experiences, there is still a mismatch between the factors that are perceived to be influential in comparison to factors that actually have influence.

Interview Findings

From the interviews, fourteen new factors were identified that may potentially impact CCPM implementation success. The identification of new factors subsequently showed that the survey was not comprehensive in nature. In addition to the new factors, the concept of sustaining CCPM in the project environment may be of interest for people considering CCPM implementation. More research is necessary to determine the impact of the fourteen newly-identified factors on CCPM implementation success and the need to consider factors during implementation that can impact the ability of the organization to sustain CCPM beyond a successful completion of the implementation process.

Some interview findings correlated with findings from the survey. One similarity between the survey and interviews was that the presence and participation of a champion for the CCPM effort was highly present and perceived to be important, even in some of the low-success attempts described in the interviews. This validates that the survey finding that the influence of the champion may not be as influential as it is perceived to be. Another similarity between the survey and interviews is that the presence of resistance was correlated with low-success implementation experiences shared by interviewees. Furthermore, a finding from the interviews is that middle management resistance, specifically, might be impacting CCPM outcomes.

Summary of Conclusions

The survey findings and interview findings can be combined to summarize specific conclusions drawn from the research. CCPM implementers will be able to use conclusions from this research to assess conditions that exist within their own organizations and focus on addressing pertinent influential factors to increase likelihood of CCPM implementation success.

The conclusions drawn from the research for multi-project CCPM implementations are listed below.

- Having an existing culture of project management practices and familiarity with the critical path method will increase the likelihood of high-success implementations.
- Pursuing CCPM to increase the chances that projects will be completed increases the likelihood of achieving high-success implementations.
- An organization needs to be able to assess the ability to clearly define scope and control scope changes throughout a project for CCPM to be successful. Frequent rescheduling and changing of priorities leads to an increased likelihood of low-success implementations.
- Buffer management needs to include the planning of actions and follow-through on those actions when the need for buffer recovery is indicated.
- Using drum buffers increases the likelihood of low-success implementations.
- Use best practices for change management techniques but focus on getting “quick wins” to show progress. Use focused communication efforts, and actively try to reduce resistance. Middle management resistance, as identified in the interviews, may specifically cause problems. One compelling way to address resistance, as identified in the interviews, is to establish buy-in for the Theory of Constraints (TOC) philosophy,

regardless of the CCPM process. There was also an indication that dissatisfaction (or resistance) for task duration estimation increases the chances of low-success implementations.

The conclusions drawn from the research for single-project CCPM implementations are listed below.

- Project size matters. Pick projects with more tasks and projects in which resources will be able to dedicate their focused effort towards each task. The inability to eliminate multitasking by resources will lead to low-success implementations.
- Build a deep understanding of CCPM and select goals for the implementation that go beyond “faster” and “on-time delivery.”
- Implement all relevant CCPM features and make sure to involve peripheral stakeholders such as customers, suppliers, and contractors in the process. Single-project implementers that use the 50% task duration estimation technique are more likely to achieve high-success implementations. Resource buffers are important, in addition to using buffer management to plan and take action as needed to recover lost buffer time.
- Using change management techniques increases the likelihood of achieving high-success implementations. Do not skip important change management steps such as training, measuring success and achieving “quick wins,” creating a vision, gaining buy-in, building ownership through customization, and having the participation of a champion for the implementation.
- Make sure that correct logical relationships are established and that multitasking is eliminated. By ensuring that both of these conditions are met, the feeding tasks will be less likely to impede progress on the critical chain. Problems associated with delayed

starts of feeding tasks and the complexity of the CCPM methodology in general were associated with low-success single-project implementations.

The general conclusions drawn from the research for multi-project and single-project CCPM implementations combined are listed below. These conclusions are valid regardless of the CCPM implementation type.

- Pursuing the following types of goals for CCPM implementation increases the likelihood of success: speed up new product introduction, increase chances that project(s) will be completed, increase quality, manage resources in a better way, increase on-time delivery, and achieve financial benefits. Subsequently, CCPM implementations that are able to measure a positive financial contribution to the organization's bottom line are more likely to achieve high-success implementations.
- Some of the most important CCPM features to implement to achieve high-success implementations include resource buffers, buffer management where buffer recovery actions are taken when needed, clear definitions of project scope(s) and definitions of tasks within the project(s), and a mentality for resources of working as quickly as possible on tasks and transferring to the next resource as soon as the task is completed.
- Important change management factors for high-success implementations include involving all peripheral stakeholders (customers, suppliers, and contractors), maintaining buy-in through the implementation, and using performance management to reinforce CCPM behaviors.

Another high-success implementation factor identified across both implementation types and the combined analysis was an increased desire for a CCPM standard. Establishment of a CCPM standard may also help guide would-be low-success implementers to achieve high-success implementations. One specific issue that resonated for all implementations was the task duration estimation techniques; publishing best practices around this specific process might reduce resistance and help implementers achieve high success.

CHAPTER 8

RECOMMENDATIONS

The survey and interview results combined indicate that additional research is needed to validate the results and investigate newly-identified factors including one factor that was not addressed as intended in the survey (lack of a CCPM standard). The factors identified in the interview, along with the factors identified via survey analysis, are described below.

- Pre-existing conditions in the organization include the number of projects in an organization, a project environment where project resources are also responsible for short-term requests, use of specific types of contracts for suppliers/contractors, and the circumstances surrounding the decision to pursue CCPM (such as having a leader with previous CCPM experience).
- A CCPM feature includes reducing the number of projects that the organization is working on at one time (reduce work-in-process).
- Change management factors include conducting an initial workshop at the beginning of the implementation and making a significant financial investment in pursuit of CCPM. Additionally, interview findings revealed that middle management, specifically, may be very influential on implementation success through the presence of resistance and buy-in.
- CCPM-specific factors include conducting an initial analysis to determine system constraints in the organization, obtaining buy-in for the Theory of Constraints (TOC) philosophy regardless of buy-in for CCPM specifically, using CCPM in conjunction with Agile methods, establishing predefined action steps to use for specific situations that might arise when using CCPM, reorganizing the project structure in an organization for compatibility with CCPM, focusing on continuous improvement as part of the CCPM

process, and using the TOC Strategy and Tactics (S&T) Tree (published by Goldratt Consulting, Inc.).

In the future, if a similar study using a survey is conducted to evaluate the influence of factors, the following recommendations may be applied:

- Obtain a larger quantity of CCPM implementation experiences, including a more representative sample of low-success experiences in comparison to high-success experiences. It is important to devise methods to specifically solicit participation from implementers with low-success experiences.
- Reduce the number of factors (shorten the survey) to bring the focus on critical factors; this may help the completion rate of the survey once accessed.
- Use a matrix-style question format instead of the star rating format for ease of lining up factors and giving participants the ability to select “not applicable.”
- Use a ten-point scale so that low-success and high-success categories for comparison are equal in size and participants are unable, by design, to select a neutral/middle position.
- Consider expanding the study to include the sustainment of CCPM as opposed to solely focusing on the CCPM implementation.

The researcher was pleased with the survey design used in this study for its ability to identify the presence of each factor in an implementation, and for the ability to use the subsequent ratings to determine influence through statistical analysis techniques. This goes beyond measurements for perception of importance that are typically used in critical success factor research. Additionally, this type of survey design can be leveraged to other topics beyond CCPM. For instance, CCPM is a very specific type of organizational change and will not draw as much attention as broader research studies into change management.

REFERENCES

AGI-Goldratt Institute. (n.d.). Retrieved from: http://www.goldratt.com/resultsoverview.shtml

Albaum, G., Wiley, J., Roster, C., & Smith, S. M. (2011). Visiting item non-responses in internet survey data collection. *International Journal of Market Research*, *53*(5), 687-703. Retrieved from Business Source Premier Database. (65509659)

Allen, I. E. & Seaman, C. A. (2007, July). Likert scales and data analysis. *Quality Progress*, *40*(7), 64-65. Retrieved from ABI/INFORM Complete Database: http://search.proquest.com.ezproxy.uwplatt.edu/docview/214764202?accountid=9253

Amberg, M., Fischl, F., & Wiener, M. (2005). Background of critical success factor research: Working paper no.2. Retrieved February 1, 2012 from: http://www.google.com/url?sa=t&rct=j&q=background%20of%20critical%20success%20factor%20research&source=web&cd=1&ved=0CCQQFjAA&url=http%3A%2F%2Fwww.international-outsourcing.de%2FCSF-Tool%2Fdocs%2FWorkingPaper_BackgroundCSF_Ambergetal._FINAL.pdf&ei=LrAqT-HJDdC42gWAn8D5Dg&usg=AFQjCNE3COYS19jD0tyXe5n4ccbE4HdHRQ&sig2=CmtAe-LVz1aRJKw2Cek4RA

Ashtiani, B., Jalali, G.-R., Aryanezhad, M.-B., & Makui, A. (2007, December). A new approach for buffer sizing in critical chain scheduling. *IEEE International Conference on Industrial Engineering and Engineering Management, December 2-4*, 1037-1041. Retrieved from IEEEXplore Database. doi:10.1109/IEEM.2007.4419350

Axinn, W. G., Link, C. F., & Groves, R. M. (2011, August). Responsive survey design, demographic data collection, and models of demographic behavior. *Demography, 48*(3), 1127-1149. doi:10.1007/s13524-011-0044-1

Balakrishnan, J. (2009). Critical chain analysis using project management software. *Production and Inventory Management Journal, 45*(1), 13-20. Retrieved from ABI/INFORM Database. (199916784)

Besner, C. & Hobbs, B. (2006, August 1). The perceived value and potential contribution of project management practices to project success. *Project Management Journal, 37*(3), 37-48. Retrieved from Business Source Premier Database. (22149374)

Besner, C. & Hobbs, B. (2008, March 1). Project management practice, generic or contextual: A reality check. *Project Management Journal*, *39*(1), 16-33. Retrieved from Business Source Premier Database. (32480492)

Besner, C. & Hobbs, B. (n.d.). Survey Report on the reality of project management practice: Phase two on an ongoing study. Retrieved from: www.pmi.org

Best, W. D. & Srinivasan, M. M. (2006, November). Critical chain project management flies. *Industrial Engineer*, *38*(11), 46-47. Retrieved from ABI/INFORM Complete Database. (231423147)

Bevilacqua, M., Ciarapica, F. E., & Giacchetta, G. (2009, May). Critical chain and risk analysis applied to high-risk industry maintenance: A case study. *International Journal of Project Management*, 2*7*(4), 419-432. doi:10.1016/j.ijproman.2008.06.006

Blackstone, J. H., Cox, J. F., Schleier, J. G. (2009, December). A tutorial on project management from a theory of constraints perspective. *International Journal of Production Research, 47*(24), 7029-7046. Retrieved from Business Source Premier Database. (44874002)

Brandt, D. R. (2003, March). CCPM's visibility problem. *Cutter IT Journal, 16*(3), 19-23. Retrieved January 16, 2012 from: http://www.prochain.com/pm/resource-center.html

Brokman, Y., Kfir, Y., & Pilovsky, Y. (2004, April). Can't see the forest for the trees? How to effectively manage complex project schedules. *Proceedings of 2004 PMI Global Congress, Prague, April 1-21*, 1-8. Retrieved from PMI: www.pmi.org (6224)

Brosnan, M. & Heath, D. (2011, Winter). Changing when change is hard. *Independent School, 70*(2), 82-88. Retrieve from Academic Search Premier. (57049310)

Bryant, M. (2006). Talking about change; Understanding employee responses through qualitative research. *Management Decision, 44*(2), 246-258. Retrieved from ABI/INFORM Complete Database: http://search.proquest.com.ezproxy.uwplatt.edu/docview/212066816?accountid=9253

Budd, C. S. & Cooper, M. J. (2005). Improving on-time service delivery: The case of project as product. *Human Systems Management, 24*(1), 67-81. Retrieved from Business Source Premier Database. (17450011)

Burton, L. J. & Mazerolle, S. M. (2011). Survey instrument validity part 1: Principles of survey instrument development and validation in athletic training education research. *Athletic Training Education Journal, 6*(1), 27-35. Retrieved from: www.nataej.org (0601-027035)

Butterfield, L. D., Borgen, W. A., Amundson, N. E., & Maglio, A.-S. T. (2005). Fifty years of the critical incident technique: 1954-2004 and beyond. *Qualitative Research, 5*, 475-497. doi:10.1177/1468794105056924

Cabanis-Brewin, J. (1999, December). "So…so what?" Debate over CCPM gets a verbal shrug from TOC guru Goldratt. *PM Network*, 13(12), 49 – 52.

Carifio, J. & Perla, R. J. (2007). Ten common misunderstandings, misconceptions, persistent myths and urban legends about Likert scales and Likert response formats and their antidotes. *Journal of Social Sciences, 3*(3), 106-116. doi:10.3844/jssp.2007.106.116

Casey, R. J. (2005, May 16). An innovative approach to schedule management on the F/A-22 major defense acquisition program (MDAP): Demonstration of critical chain project management. *ProQuest Dissertations and Theses*. Retrieved from ABI/INFORM Complete Database. (305382575)

Cerveny, J. & Galup, S. (2002). Critical chain project management holistic aligning quantitative and qualitative project management methods. *Production and Inventory Management Journal*, *43*(3/4), 55-64. Retrieved from ABI/INFORM Complete Database. (199911472)

Chen, G. & Sun, Q. (2010, May). The study on setting method of project buffers in a critical chain. *Proceedings of the 2010 International Conference on E-Business and E-Government (ICEE), May 7-9*, 2851-2854. Retrieved from IEEEXplore Database. doi:10.1109/ICEE.2010.720

Chen, M. & Peng, W. (2009, May). An active plan based on critical chain method. *Proceedings of the Chinese Control and Decision Conference (CCDC '09), May 23-25*, 2765-2769. Retrieved from IEEEXplore Database. doi:10.1109/CCDC.2009.5194975

Chrusciel, D. & Field, D. W. (2003). From critical success factors into criteria for performance excellence – An organizational change strategy. *Journal of Industrial Technology, 19*(4), 1-11. Retrieved February 1, 2012 from: atmae.org/jit/Articles/chrusciel073003.pdf

Cicmil, S., Williams, T., Thomas, J., & Hodgson, D. (2006). Rethinking project management: Researching the actuality of projects. *International Journal of Project Management, 24*, 675-686. doi:10.1016/j.ijproman.2006.08.006

Cohen, I., Mandelbaum, A., & Shtub, A. (2004, June). Multi-project scheduling and control: A process-based comparative study of the critical chain methodology and some alternatives. *Project Management Journal, 35*(2), 39-50. Retrieved from Business Source Premier Database. (13380400)

Creasey, T. (2012, April 26). Prosci change management webinar: Greatest contributors and biggest obstacles [Webinar]. Prosci Inc.

CriticalChain. (n.d.). Members. Retrieved February 28, 2012 from LinkedIn CriticalChain Group: http://www.linkedin.com/groups?viewMembers=&gid=50180&sik=1330461128482

Critical Chain Professional. (n.d.). Members. Retrieved May 17, 2012 from LinkedIn Critical Chain Professional Group: http://www.linkedin.com/groups?viewMembers=&gid=2289854&sik=1338690756742

Croteau, A.-M. & Li, P. (2003, March). Critical success factors of CRM technological initiatives. *Canadian Journal of Administrative Sciences, 20*(1), 21-34. Retrieved from Business Source Premier Database. (9675552)

Cui, N., Tian, W., & Bie, L. (2010). Rescheduling after inserting the buffer in the critical chain scheduling. *2010 International Conference on Logistics Systems and Intelligent Management, 2*, 1105-1110. Retrieved from IEEEXplore Database. doi:10.1109/ICLSIM.2010.5461129

Davis, L., Samanlioglu, F., Stanfield, P,, & Davis, J. (2006, May). Systemized critical chain project management with application to remanufacturing. *IIE Annual Conference: Proceedings, May 22-24*, 1-6. Retrieved from ABI/INFORM Complete Database. (192460642)

Dawes, J. (2008). Do data characteristics change according to the number of scale points used? An experiment using 5-point, 7-point and 10-point scales. *International Journal of Market Research, 50*(1), 61-77. Retrieved from Business Source Premier Database. (27996447)

De Reyck, B. (2010). Effective project planning: Making the most of project planning tools. *Production and Inventory Management Journal, 46*(2), 10-25. Retrieved from ABI/INFORM Complete Database. (854004134)

De Saram, D. D., Ahmed, S. M., & Anson, M. (2004, July). Suitability of the Critical Incident Technique to measure quality of construction coordination. *Journal of Management in Engineering, 20*(3), 97-109. doi:10.1061/~ASCE!0742-597X~2004!20:3~97!

Dezdar, S. & Sulaiman, A. (2009). Successful enterprise resource planning implementation: Taxonomy of critical factors. *Industrial Management & Data Systems, 109*(8), 1037-1052. doi:10.1108/02635570910991283

Dittrich, R., Francis, B., Hatzinger, R., & Katzenbeisser, W. (2007). A paired comparison approach for the analysis of sets of Likert-scale responses. *Statistical Modeling, 7*(1), 3-28. doi:10.1177/1471082X0600700102

Dolye, J. K. (2010, April). Critical chain exercises. *American Journal of Business Education. 3*(4), 43-49. Retrieved from ABI/INFORM Complete Database. (195899871)

Duc Long, L., & Ohsato, A. (2008, August). Fuzzy critical chain method for project scheduling under resource constraints and uncertainty. *International Journal of Project Management, 26*(6), 688-698. doi:10.1016/j.ijproman.2007.09.012

Duncan, W. R. (1999, April). Back to basics: Charters, chains, and challenges. *PM Network, 13*(4), 29-30. Retrieved from PMI: www.pmi.org (2979)

Elton, J. & Roe, J. (1998, March/April). Bringing discipline to project management. *Harvard Business Review*, *76*(2), 153-159. Retrieved from Business Source Premier Database. (299075)

Filiatrault, C. L. G. & Peterson, C. D. (2000, September). Five behaviors that can reduce schedule risk. *Proceedings of the Project Management Institute (PMI) Annual Seminars & Symposium, September 7-16*, 953-957. Retrieved from PMI: www.pmi.org (1475)

Finney, S. & Corbett, M. (2007). ERP implementation: a compilation and analysis of critical success factors. *Business Process Management Journal, 13*(3), 329-347. doi:10.1108/14637150710752272

Fortune, J. & White, D. (2006). Framing of project critical success factors by a systems model. *International Journal of Project Management, 24*, 53-65. doi:10.1016/j.ijproman.2005.07.004

Françoise, O., Bourgault, M., & Pellerin, R. (2009). ERP implementation through critical success factors' management. *Business Process Management Journal*, *15*(3), 371-394. doi:10.1108/14637150910960620

Friedman, L. (1990). Degree of redundancy between time, importance, and frequency task ratings. *Journal of Applied Psychology, 75*(6), 748-752. doi:10.1037/0021-9010.76.3.366 (apl-75-6-748)

Gaines, K. (2002). Writing a master's thesis or dissertation proposal. Retrieved February 21, 2012 from: http://www.gwr.arizona.edu/writingproposal1.htm

Gao, P., Feng, J., & Wang, H. (2007, June). Grey critical chain project scheduling technique and its application. *Canadian Social Science, 3*(3), 35-41. Retrieved from ABI/INFORM Complete Database. (208631702)

García-Sánchez, N. & Pérez-Bernal, L. E. (2007). Determination of Critical Success Factors in implementing an ERP system: A field study in Mexican enterprises. *Information Technology for Development*, *13*(3), 293-309. doi:10.1002/itdj.20075

Gardner, P. J. (2009). Organizational change: All we want is better projects – Why so difficult? *AACE International Transactions*, PM.03.1 – PM.03.25. Retrieved from Business Source Premier Database. (48225949)

Globerson, S. (2000, May). PMBOK and the critical chain. *PM Network*, *14*(5), 63-66.

Göb, R., McCollin, C., & Ramalhoto, M. F. (2007). Ordinal methodology in the analysis of Likert scales. *Quality & Quantity*, *41*(5), 601-626. doi:10.1007/s11135-007-9089-z

Goldratt, E. M. (1997). *Critical chain*. Great Barrington, MA: North River Press.

Gray, V., Felan, J., Umble, E., & Umble, M. (2000, June). A comparison of drum-buffer-rope (DBR) and critical chain (CC) buffering techniques. *Proceedings of PMI Research Conference, June 21-24, Paris, France, 257-264.* Retrieved from PMI: www.pmi.org (2998)

Gupta, S. (2003, November). My project epiphany. *PM Network, 17*(11), 20-21. Retrieved from H. W. Wilson Database. (10408754)

Gupta, S. (2005, September). Speeding development. *Appliance Design*, *53*(9), 30-35. Retrieved from ABI/INFORM Complete Database. (194711390)

Gupta, S. (2008, May/June). Earned value management clogs profits. *Industrial Management, 50*(3), 12-16. Retrieved from ABI/INFORM Complete Database. (211638272)

Gupta, S. (2010, August). More success in managing pipeline projects. *Pipeline & Gas Journal, 237*(8), 56-60. Retrieved from ABI/INFORM Complete Database. (749697827)

Gupta, S. (2011, March/April). Completing turnaround projects faster with full scope. *Electric Light and Power*, *89*(2), 36-39. Retrieved from ABI/INFORM Complete Database. (865935595)

Hagemann, A. G. (2001). Use of the critical chain project management technique at NASA, Langley Research Center. *The 20th Conference Digital Avionics Systems (DASC), 1*, 4B1/1-4B1/10. Retrieved from IEEEXplore Database. doi:10.1109/DASC.2001.963368

Härtel, C. E. J. (1993). Rating format research revisited: Format effectiveness and acceptability depend on rater characteristics. *Journal of Applied Psychology, 78*(2), 212-217. doi:10.1037/0021-9010.78.2.212

Herroelen, W. & Leus, R. (2001). On the merits and pitfalls of critical chain scheduling. *Journal of Operations Management*, *19*, 559-577. PII: S0272-6963(01)00054-7

Herroelen, W. & Leus, R. (2004, April 15). Robust and reactive project scheduling: A review and classification of procedures. *International Journal of Production Research, 42*(8), 1599-1620. doi:10.1080/00207540310001638055

Herroelen, W. & Leus, R. (2005, January). Identification and illumination of popular misconceptions about project scheduling and time buffering in a resource-constrained environment. *Journal of the Operational Research Society, 56*(1), 102-109. doi:10.1057/palgrave.jors.2601813

Herroelen, W., Leus, R., & Demeulemeester, E. (2002). Critical chain project scheduling: Do not oversimplify. *Project Management Journal, 33*(4), 48-60. Retrieved from Business Source Premier Database. (8603025)

Higgins, D. (2003, March). CCPM's visibility problem. *Cutter IT Journal, 16*(3), 5-9. Retrieved January 16, 2012 from: http://www.prochain.com/pm/resource-center.html

Higgs, M. & Rowland, D. (2010, December). Emperors with clothes on: The role of self-awareness in developing effective change leadership. *Journal of Change Management, 10*(4), 369-385. doi:10.1080/14697017.2010.516483

Hinkin, T. R. (1995). A review of scale development practices in the study of organizations. *Journal of Management, 21*(5), 967-988. Retrieved from Business Source Premier Database. (9512044424)

Hinkin, T. R. (1998). A brief tutorial on the development of measures for use in survey questionnaires. *Organizational Research Methods, 1*, 104-121. doi:10.1177/109442819800100106

Hodge, D. R. & Gillespie, D. F. (2003). Note on research methodology. Phrase completions: An alternative to Likert scales. *Social Work Research, 27*(1), 45-55. Retrieved from: www.cinahl.com/cgi-bin/refsvc?jid=958&accno=2003092147

Hodge, D. R. & Gillespie, D. F. (2007). Phrase completion scales: A better measurement approach than Likert scales? *Journal of Social Service Research, 33*(4), 1-12. Retrieved from: http://dx.doi.org/10.1300/J079v33n04_01

Hoel, K. & Taylor, S. G. (1999). Quantifying buffers for project schedules. *Production and Inventory Management Journal – Second Quarter, 40(*2), 43-47. Retrieved from ABI/INFORM Complete Database. (199909783)

Homer, J. L. (1998, October). Applying the Theory of Constraints to projects. *Proceedings of the 29th Annual Project Management Institute 1998 Seminars & Symposium, Long Beach, California, October 9-15, 2*, 1144-1148. Retrieved from PMI: www.pmi.org (3547)

How statistically valid are your survey results? Why the survey response rate is important? (n.d.). Retrieved from: www.mpiweb.org/cms/.../1136860_7142008_100418_am_.pdf

Huang, X-B. & Yang, L-X. (2009). Setting lead-time in project manufacturing environment based on CCPM. *International Conference on Apperceiving Computing and Intelligence Analysis (ICACIA), 2009*, 407-410. Retrieved from IEEEXplore Database. doi:10.1109/ICACIA.2009.5361070

Iivari, J. & Huisman, M. (2007, March). The relationship between organizational culture and the deployment of systems development methodologies. *MIS Quarterly, 31*(1), 35-58. Retrieved from Business Source Premier Database. (23963630)

Jacoby, J. & Matell, M. S. (1971, November). Three-point Likert scales are good enough. Journal of Marketing Research, 8(4), 495-500. Retrieved from ABI/INFORM Complete Database: http://search.proquest.com.ezproxy.uwplatt.edu/docview/208757478?accountid=9253

Jamieson, S. (2004, December). Likert scales: How to (ab)use them. *Medical Education, 38*(12), 1217-1218. Retrieved from CINAHL Plus with Full Text Database. (2009401436)

Kasahara, M., Takahashi, H., & Goto, H. (2009, August). On the buffer management policy for CCPM based on MPL. *Proceedings of the ICROS-SICE International Joint Conference, August 18-21*, 1711-1716. Retrieved from IEEEXplore Database. (05334983)

Kim, E.H., Wells, W. G., Jr., & Duffey, M. R. (2003). A model for effective implementation of Earned Value Management methodology. *International Journal of Project Management, 21*, 375-382. doi:10.1016/S0263-7863(02)00049-2

Kotter, J. P. (1995, March/April). Leading change: Why transformation efforts fail. *Harvard Business Review, 73*(2), 59-67. Retrieved from Business Source Premier Database. (9503281992)

Kotter, J. P. & Cohen, D. S. (2002). The heart of change: Real-life stories of how people change their organizations [Electronic Book]. Retrieved from University of Wisconsin – Platteville: http://ezproxy.uwplatt.edu:2048/login?url=http://www.netlibrary.com/urlapi.asp?action=summary& v=1& bookID=79102

Kuo, T.-C., Chang, S.-H., & Huang, S.-N. (2009, March). Due-date performance improvement using TOC's aggregated time buffer method at a wafer fabrication factory. *Expert Systems with Applications*, *36*(2), 1783-1792. doi:10.1016/j.eswa.2007.12.038

KwikSureys.com. (n.d.). Version 47.0. Accessed from: www.kwiksurveys.com

Leach, L. P. (1998, October). Critical chain project management. *Proceedings of the 29th Annual Project Management Institute 1998 Seminars & Symposium, Long Beach, CA, October 9-15*, 1-7. Retrieved from PMI: www.pmi.org (3565)

Leach, L. P. (1999a, June). Critical chain project management improves project performance. *Project Management Journal, 30*(2), 39-51. Retrieved from Business Source Premier Database. (1992225)

Leach, L. P. (1999b, December). Correspondence. *Project Management Journal*, *13*(12), 61.

Leach, L. P. (2001, March). Putting quality in project risk management part 2: Dealing with variation. *PM Network*, *15*(3), 47-52.

Leach, L. P. (2003, June). Schedule and cost buffer sizing: How to account for the bias between project performance and your model. *Project Management Journal*, *34*(2), 34-47. Retrieved from Business Source Premier Database. (9972101).

Leach, L. P. (2005). *Critical Chain Project Management (2nd ed.)*. Norwood, MA: Artech House Publishers.

Leach, L. P. (2011, October). Buffers: Key to project schedule success. *PM World Today, XIII*(X), 1-16. Retrieved from: www.pmforum.org/library/papers/2011/PDFs/oct/FP-LEACH.pdf

Lechler, T., Ronen, B., & Stohr, E. A. (2005a, January 28). Critical chain project management: High potential – Hard to achieve [PowerPoint Presentation].

Lechler, T., Ronen, B., & Stohr, E. A. (2005b, December). Critical chain: A new project management paradigm or old wine in new bottles? *Engineering Management Journal, 17*(4), 45-58. Retrieved from ABI/INFORM Complete Database. (208950300)

Lee, B. & Miller, J. (2004, March). Multi-project management in software engineering using simulation modeling. *Software Quality Journal*, *12*(1), 59-82. doi:10.1023/B:SQJO.0000013359.71560.47

Leung, S.-O. (2011). A comparison of psychometric properties and normality in 4-, 5-, 6-, and 11-point Likert scales. *Journal of Social Service Research*, *37*(4), 412-421. Retrieved from: http://dx.doi.org/10.1080/01488376.2011.580697

Levine, H. A. (1999, October). Shared contingency; Exploring the critical chain. *PM Network, 13*(10), 35-38.

Li, K. & Chen, Y-x. (2007, December). Applying critical chain in project scheduling and estimating buffer size based on fuzzy technique. *IEEE International Conference on Industrial Engineering and Engineering Management, December 2-4*, 1068-1072. doi:10.1109/IEEM.2007.4419356

Li, K., Gong, L., & Kou, J. (2009, October). Resource-constrained project scheduling based on ACO-critical chain method. *Proceedings of the Second International Workshop on*

Computer Science and Engineering (WCSE '09), October 28-30, 485-489. Retrieved from IEEEXplore Database. doi:10.1109/WCSE.2009.858

Liu, J.-B., Ren, H., & Xie, J.-H.. (2008, December). Critical chain project management based heuristic algorithm for multiple resources-constrained project. *Proceedings of International Seminar on Business and Information Management (ISBIM '08).* Retrieved from IEEEXplore Database. doi: 10.1109/ISBIM.2008.96

Liu, Q., Liu, N., & Ullah, S. (2009, October). A task group based multi-order critical chain identification algorithm. *Proceedings of the IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), October 28-30*, 1494-1498. Retrieved from IEEEXplore Database. doi:10.1109/IEEM.2009.5373077

Lubke, G. & Neale, M. (2008, October-December). Distinguishing between latent classes and continuous factors with categorical outcomes: Class invariance of parameters of factor mixture models. *Multivariate Behavioral Research, 43*, 592-620. doi:10.1080/00273170802490673

Lynch, B. (2003, March). Opening statement. *Cutter IT Journal, 16*(3), 2-4. Retrieved January 16, 2012 from: http://www.prochain.com/pm/resource-center.html

Matell, M. S. & Jacoby, J. (1972). Is there an optimal number of alternatives for Likert-scale items? Effects of testing time and scale properties. *Journal of Applied Psychology, 56*(6), 506-509. doi:10.1037/h0033601

Mecham, M. (2011, August 22). No multitasking. *Aviation Week & Space Technology*, *173*(30). Retrieved from Business Source Premier Database. (00052175)

Michalski, L., Miller, J., & Levin-Epstein, M. (2000, September). Applying the theory of constraints. *Biopharm International, 13*(9), 24-28. Retrieved from ABI/INFORM Complete Database. (195737912)

Milosevic, D. Z. (2003). *Project management toolbox: Tools and techniques for the practicing project manager*. Hoboken, NJ: John Wiley & Sons, Inc.

Minitab Inc. (2007). Minitab 15 English [Computer software].

Miranda, E. (2002, March). Planning and executing time-bound projects. *Computer, 35*(9), 73-79. doi:10.1109/2.989933

Miranda, E. (2004, April). Combining critical chain planning and incremental development in software projects. *Proceedings of 2004 PMI Global Congress, Prague, April 1-21*,1-12. Retrieved from PMI: www.pmi.org (6256)

Monash University. (2007). Writing a research thesis. Retrieved May 23, 2012 from: http://www.education.monash.edu.au/students/current/study-resources/thesiswriting.html

Myford, C. M. (2002). Investigating design features of descriptive graphic rating scales. *Applied Measurement in Education*, *15*(2), 187-215. Retrieved from Academic Search Premier Database. (6672646)

Nye, C. D., Brummel, B. J., & Drasgow, F. (2010, November). Too good to be true? Understanding change in organizational outcomes. *Journal of Management, 36*(6), 1555-1577. doi:10.1177/0149206310376326

Oren, R. A. (2009, August). Contributory success factors for projects with the project management profession: A quantitative analysis. *ProQuest Dissertations and Theses*. Retrieved from ABI/INFORM Complete Database. (305162558)

Patrick, F. S. (1999a, April). Getting out from between Parkinson's rock and Murphy's hard place. *PM Network, 13*(4), 57-62. Retrieved from PMI: www.pmi.org (1940)

Patrick, F. S. (1999b, October). Program management—Turning many projects into few priorities with TOC. *Proceedings of the 30th Annual Project Management Institute 1999 Seminars & Symposium, Philadelphia, PA, October 10-16*, 1-5. Retrieved from PMI: www.pmi.org (2128)

Patrick, F. S. (2001, November). Buffering against risk—Critical chain and risk management. *Proceedings of the Project Management Institute (PMI) Annual Seminars & Symposium, November 1-10*. Retrieved from PMI: www.pmi.org (702)

Pell, G. (2005). Use and misuse of Likert scales. *Medical Education, 39*(9), 970-971. Retrieved from CINAHL Plus with Full Text Database. (2009297878)

Percy, L. (1976). An argument in support of ordinary factor analysis of dichotomous variables. *Advances in Consumer Research, 3*(1), 143-148. Retrieved from Business Source Premier Database. (6597670)

Perkins, T. K. (2001, January). Project scheduling according to Dr. Goldratt. *CROSSTALK: The Journal of Defense Software Engineering*, 19-21. Retrieved October 21, 2011 from: http://www.crosstalkonline.org/storage/issue-archives/2001/200101/200101-perkins.pdf

Perterson, C. D. & Filiatrault, C. L. (2000, September). Earned value vs. critical chain project management. *Proceedings of the Project Management Institute Annual Seminars & Symposium September 7-16, Houston, Texas*. Retrieved from Project Management Institute: www.pmi.org (1439)

Peterson, C. D., Oliver, M., & Webb, S. (2002). What makes earned value and other advanced PM techniques so hard to successfully implement? *Proceedings of the Project*

Management Institute Annual Seminars & Symposium, October 3-10, San Antonio, TX, 1-5. Retrieved from PMI: www.pmi.org (3189)

Piney, C. (2000, December). Critical path or critical chain; Combining the best of both. *PM Network*, *14*(12), 51-54.

Pinto, J. K. & Mantel, S. J., Jr. (1990, November). The causes of project failure. *IEEE Transactions of Engineering Management*, *37*(4), 269-276. doi:10.1109/17.62322

Pinto, J. K. (1999, August). Some constraints on the Theory of Constraints: Taking a critical look at the critical chain. *PM Network*, *13*(8), 49-51. Retrieved from PMI: www.pmi.org (1966)

Pinto, J. K. (2002, March/April). Project management 2002. *Research Technology Management*, *45*(2), 22-37. Retrieved from ABI/INFORM Complete Database. (213806166)

Prochain Solutions Inc. (n.d.) Retrieved from: http://www.prochain.com/clients/results.html

Project Management Institute, Inc. (2006). *Practice standard for work breakdown structures* (2nd Ed.). Newton Square, PA: Project Management Institute, Inc.

Project Management Institute, Inc. (2008). *A guide to the project management body of knowledge (PMBOK Guide)* (4th ed.). Newton Square, PA: Project Management Institute, Inc.

Project Management Institute. (n.d.). Scheduling Community of Practice (SCoP) member directory. Retrieved February 28, 2012 from: http://scheduling.vc.pmi.org/Members.aspx

Prosci. (n.d.). Prosci change management webinars: Greatest contributors and biggest obstacles to success [Handout]. Retrieved from: www.change-management.com

Rabbani, M., Fatemi Ghomi, S. M. T., Jolai, F., & Lahiji, N. S. (2007, January 16). Discrete optimization: A new heuristic for resource-constrained project scheduling in stochastic networks using critical chain concept. *European Journal of Operational Research, 176*(2), 794-808. doi:10.1016/j.ej.or.2005.09.018 (1630303)

Ramgopal, M. (2003, December). Project uncertainty management. *Cost Engineering, 45*(12), 21-24. Retrieved from ABI/INFORM Complete Database. (220438598)

Rand, G. K. (2000, June 1). Critical chain: The theory of constraints applied to project management. *International Journal of Project Management, 18*(3), 173-177. Retrieved December 20, 2011 from: http://www.google.com/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=7&ved=0CGIQFjAG&url=http%3A%2F%2Fwww.kth.se%2Fpolopoly_fs%2F1.222013!%2FMenu%2Fgeneral%2Fcolumn-content%2Fattachment%2FArticle3-Rand.pdf&ei=9KnwToLEEMHt0gGmm92UBA&usg=AFQjCNExVdGBhC0U8QWTiVr-xxolr3TS7Q&sig2=8iAug_VoIDmCtCUHzTIo6w

Rasmussen, J. L. (1989). Analysis of Likert-scale data: A reinterpretation of Gregoire and Driver. *Psychological Bulletin, 105*(1), 167-170. doi:10.1037/0033-2909.105.1.167

Raz, T., Barnes, R., & Dvir, D. (2003, December). A critical look at critical chain project management. *Project Management Journal, 34*(4), 24-32. Retrieved from Business Source Premier Database. (11583969)

Realization. (2004). Key learnings. Retrieved January 16, 2012 from: http://www.realization.com/lessons-learned.html

Realization. (2005). Lessons learned. Retrieved January 16, 2012 from: http://www.realization.com/lessons-learned.html

Realization. (2006). Lessons learned. Retrieved January 16, 2012 from: http://www.realization.com/lessons-learned.html

Realization. (2007). Lessons learned. Retrieved January 16, 2012 from: http://www.realization.com/lessons-learned.html

Realization. (2008). Lessons learned. Retrieved January 16, 2012 from: http://www.realization.com/lessons-learned.html

Realization. (2009). Lessons learned. Retrieved January 16, 2012 from: http://www.realization.com/lessons-learned.html

Realization. (2010). Lessons learned. Retrieved January 16, 2012 from: http://www.realization.com/lessons-learned.html

Realization. (n.d.). Retrieved from: http://www.realization.com/results.html

Response and non-response. (2011). Retail Trade, 83(9), 71-73. Retrieved from Business Source Premier Database. (67741416)

Rezaie, K., Manouchehrabadi, B., & Shirkouhi, S. N. (2009, May). Duration estimation, a new approach in critical chain scheduling. *Proceedings of the Third Asia International Conference on Modelling & Simulation (AMS '09), May 25-29*, 481-484. Retrieved from IEEEXplore Database. doi:10.1109/AMS.2009.67

Rivera, F. A. & Duran, A. (2004, August). Critical clouds and critical sets in resource-constrained projects. *International Journal of Project Management*, *22*(6), 489-497. doi:10.1016/j.ijproman.2003.11.004

Rizzo, T. (1999a, November). Operational measurements for product development organizations – Part 1. *PM Network*, *13*(11), 42-47. Retrieved from PMI: www.pmi.org (2014)

Rizzo, T. (1999b, December). Operational measurements for product development organizations – Part 2. *PM Network*, *13*(12), 31-35. Retrieved from PMI: www.pmi.org (2019)

Robinson, H. & Richards, R. (2009). An introduction to critical change project management. *AACE International Transactions*, PS.S03.1-PS.S03.11. Retrieved from Business Source Premier Database. (48225963)

Russell, C. J. & Bobko, P. (1992, June). Moderated regression analysis and Likert scales: Too coarse for comfort. *Journal of Applied Psychology, 77*(3), 336-342. doi:10.1037/0021-9010.77.3.336

Scherer, A. (2011). *Be fast or be gone: Racing the clock with critical chain project management*. Lake Ridge, VA: ProChain Solutions, Inc.

Scherschel, B. (2002, October). Program management using TOC and CCM. *Proceedings of the Project Management Institute (PMI) Annual Seminars & Symposium, October 3-10, San Antonio, TX*, 1-5. Retrieved from PMI: www.pmi.org (3173)

Schuyler, J. (2000a, January). Exploiting the best of critical chain and Monte Carlo simulation. *PM Network*, *14*(1). 56-60.

Schuyler, J. (2000b, March). Optimizing project plan decisions. *PM Network*, *14*(3), 65-68.

Shi, Q. & Gong, T. (2009, November). An improved project buffer sizing approach to critical chain management under resources constraints and fuzzy uncertainty. *Proceedings of the 2009 International Conference on Artificial Intelligence and Computation Intelligence, November 7-8*, 486-490. Retrieved from IEEEXplore Database. doi:10.1109/AICI.2009.192 (05376276)

Shore, B. (2008, December). Systematic biases and culture in project failures. *Project Management Journal*, *39*(4), 5-16. doi:10.1002/pmj.20082

Shou, Y. & Yao, K.T. (2000). Estimation of project buffers in critical chain project management. *Proceedings of the 2000 IEEE International Conference on Management of Innovation* *and Technology (ICMIT), 1*, 162-167. Retrieved from IEEEXplore Database. doi:10.1109/ICMIT.2000.917313

Shulruf, B., Hattie, J., & Dixon, R. (2008). Factors affecting responses to Likert type questionnaires: Introduction of the ImpExp, a new comprehensive model. *Social Psychology of Education, 11*(1), 59-78. doi:10.1007/s11218-007-9035-x

Simpson III, W. P. (2010). Project planning and control when time matters: Focus on process to synchronize and drive results. *Production and Inventory Management Journal, 46*(2), 26-43. Retrieved from ABI/INFORM Complete Database. (854003682)

Simpson, W. P., III, & Lynch, W. (1999, October). Critical success factors in critical chain project management. *Proceedings of the 30th Annual Project Management Institute 1999 Seminars & Symposium, Philadelphia, PA, October 10-16,* 1-4.

Smith-Daniels, D. E. & Aquilano, N. J. (1987, October). Using a late-start resource-constrained project schedule to improve project net present value. *Decision Sciences, 18*(4), 617-630. doi:10.1111/j.1540-5915.1987.tb01550.x

Soja, P. (2006). Success factors in ERP systems implementations: Lessons from practice. *Journal of Enterprise Information Management, 19*(6), 646-661. doi:10.1108/17410390610708517

Sood, S. (2002, October). Critical chain buffering. *Drug Discovery & Development, 5*(9), 86-87. Retrieved from Academic Search Premier Database. (7621132)

Sood, S. (2003, March). Taming uncertainty; Critical-chain buffer management helps minimize risk in the project equation. *PM Network, 17*(3), 57-59. Retrieved from PMI: www.pmi.org (4423)

Spanholtz, D. & Stokes, J. (2000, June). New thinking pays off for plant project. *PM Network*, *14*(6), 36-38. Retrieved from PMI: www.pmi.org (1262)

Spoede, C. W. & Jacob, D. B. (2002, December). Policing, firefighting, or managing? *Strategic Finance*, *84*(6), 31-35. Retrieved from ABI/INFORM Complete Database. (229811327)

Steyn, H. (2002). Project management applications of the theory of constraints beyond critical chain scheduling. *International Journal of Project Management*, *20*(1), 75-80. Retrieved December 20, 2011 from: http://www.google.com/url?sa=t&rct=j&q=herman%20steyn%20critical%20chain&source=web&cd=9&sqi=2&ved=0CHAQFjAI&url=http%3A%2F%2F200.17.137.109%3A8081%2Fxiscanoe%2FMembers%2Fvollare%2Fcontingency-reserve-and-managment-reserve-in-software-engineering%2FProject%2520management%2520applications%2520of%2520the%2520theory%2520of%2520constraints%2520beyond%2520critical%2520chain%2520scheduling.pdf&ei=Pq3wTrCxBInu0gGln7m9Ag&usg=AFQjCNGLrdGLmAd5hfv5_4cQnaV1svm8CQ&sig2=7b0p3WwRQqMC9WCYuUaVHA&cad=rjt

Stratton, R. (2009, May). Critical chain project management theory and practice. *Proceedings of the POMS 20th Annual Conference, Orlando, FL, May 1-4*, 1-31. Retrieved January 6, 2012 from: www.pomsmeetings.org/ConfPapers/011/011-0754.pdf

SurveyMonkey. (n.d.). Smart Survey Design. Retrieved February 2, 2012 from: s3.amazonaws.com/SurveyMonkeyFiles/SmartSurvey.pdf

Suwa, H., Morita, D., & Sandoh, H. (2010, March/April). A new framework of critical chain scheduling in project management. *Proceedings of the 2010 Second International*

Conference on Engineering Systems Management and its Applications (ICESMA), March 30 - April 1, 1-6. Retrieved from IEEEXplore Database. (05542686)

Takahashi, H., Goto, H., & Kasahara, M. (2009, March). Application of a critical chain project management based framework on max-plus linear systems. *Proceedings of the 3rd International Conference on Complex, Intelligent and Software Intensive Systems (CISIS '09), March 16-19*, 898-903. Retrieved from IEEEXplore Database. doi:10.1109/CISIS.2009.66

Tan, W.-G., Cater-Steel, A., & Toleman, M. (2010, Winter). Implementing IT service management: A case study focusing on critical success factors. *Journal of Computer Information Systems, 50*(2), 1-12. Retrieved from Business Source Premier Database. (48216609)

Taylor, A. G. & Rafai, S. (2003, Fall). Strategic budgeting: A case study and proposed framework. *Management Accounting Quarterly, 5*(1), 1-10. Retrieved from ABI/INFORM Complete Database. (222801793)

Tenera, A. & Abreu, A. (2008, May). Management of dynamic production network from a critical chain perspective. *Proceedings of the 2008 Industrial Engineering Research Conference, May 17-21*, 1013-1018. Retrieved from ABI/INFORM Complete Database. (192465126)

Tenera, A. B. (2008, July). Critical chain buffer sizing: A comparative study. *Proceedings of PMI Research Conference, July 13-16*. Retrieved from Project Management Institute: www.pmi.org (9348)

Tenera, A., Machado, V. C. (2007, May). Critical chain project management: A new approach for time buffer sizing. *Proceedings of IIE Annual Conference, May 19-23*, 475-480.

Tian, Z., Zhang, Z., & Peng, W. (2010, July). A critical chain based multi-project management plan scheduling method. *Proceedings of the 2010 2nd International Conference on Industrial and Information Systems (IIS), July 10-11*, 304-308. Retrieved from IEEEXplore Database. doi:10.1109/INDUSIS.2010.5565711

Trietsch, D. (2005, March). Why critical path by any other name would smell less sweet? *Project Management Journal, 36*(1). Retrieved from H. W. Wilson Database. (87569728)

Tukel, O. & Rom, W. (2006, July). Analysis of resource buffer management in critical chain scheduling. *Proceedings of PMI Research Conference 2006, July 16-19*. Retrieved from Project Management Institute: www.pmi.org (7961)

Tukel, O. I., Ron, W. O., & Eksioglu, S. D. (2006, July 16). Production, manufacturing, and logistics: An investigation of buffer sizing techniques in critical chain scheduling. *European Journal of Operational Research, 172*(2), 401-416. doi:10.1016/j.ejor.2004.10.019

Umble, M. & Umble, E. (2000). Manage your project for success: An application of the theory of constraints. *Production and Inventory Management Journal – Second Quarter, 41*(2), 27-32. Retrieved from ABI/INFORM Complete Database. (199947778)

University of Wisconsin-Platteville Graduate Council. (2009, February). Standards and procedures for approved master's theses; University of Wisconsin-Platteville requirements. Retrieved January 19, 2012 from: www.uwplatt.edu/library/reference/guidemastersthesisuwp.pdf

Uyttewaal, E. (1999, December). Take the path that is really critical. *PM Network, 13*(12), 37-39.

Van Bennekom, F. (2003). Statistical accuracy of a survey [PowerPoint Slides]. Retrieved from: www.greatbrook.com

VanOverloop, M. & Peterson, S. A. (2009, September). Application of CCPM in ATE program management. *Proceedings of the AUTOTESTCON, September 14-17, Anaheim, CA*, 384-388. Retrieved from IEEEXplore Database. doi:10.1109/AUTEST.2009.5314029

Vinson, J. (2011, August). Critical chain software [Update]. Knowledge Jolt with Jack [blog]. Retrieved April 19, 2011 from: http://blog.jackvinson.com/archives/2003/07/24/critical_chain_software.html

Wadia, A. & Parkinson, D. (2010). How to design and use free online surveys to collect feedback on your services. Retrieved February 2, 2012 from Monitoring and Evaluation Consulting Website: http://monitoringandevaluation.org.uk/publications.htm

Wang, J. Q., Zhang, S. F., Chen, J., Wang, S., & Zhang, Y. F. (2011, September). Three-dimensional Gantt chart based resource-constrained multiple projects scheduling and critical chain identification. *Proceedings of the 2011 IEEE 18th International Conference on Industrial Engineering and Engineering Management (IE&EM), September 3-5, Part 3*, 1597-1601. Retrieved from IEEEXplore Database. doi:10.1109/ICIEEM.2011.6035465

Wang, X., Bai, Y., Cai, C., & Yan, X. (2010, July). Application of resource-constrained project scheduling with a critical chain method on organizational project management. *Proceedings of the 2010 International Conference on Computer Design and Applications (ICCDA), July 25-27*, V2-51 – V2-54. Retrieved from IEEEXplore Database. doi:10.1109/ICCDA.2010.5541070

Wang, Y. (2011, August). Study on critical chain project portfolio management. *Proceedings of the 2011 International Conference on Management and Service Science (MASS), August 12-14*, 1-4. Retrieved from IEEEXplore Database. doi:10.1109/ICMSS.2011.5998173

Watson K. J., Blackstone, J. H., & Gardiner, S. C. (2007, March). The evolution of a philosophy: The theory of constraints. *Journal of Operations Management, 25*(2), 387-402.

Wiest, J. D. (1964). Some properties of schedules for large projects with limited resources. *Operations Research, 12*, 395-418. Retrieved from Informs: Institute for Operations Research.

Wiest, J. D. (1967, February). A heuristic model for scheduling large projects with limited resources. *Management Science, 13*(6), B-359 – B-377. Retrieved from Business Source Premier Database. (7028812)

Wilkens, T. T. (2000, July). Critical path, or chain, or both? *The PM Network, 14*(7), 68-74.

Yang, J.-B. (2007, April). How the critical chain scheduling method is working for construction. *Cost Engineering, 49*(4), 25-32. Retrieved from Business Source Premier Database. (24876586)

Yang, L., Fu, Y., Li, S., Huang, B., & Tao, P. (2008, June). A buffer sizing approach in critical chain scheduling with attributes dependent. *Proceedings of the 4th International Conference on Wireless Communications, Networking and Mobile Computing, June 25-27*, 1-4. Retrieved from IEEEXplore Database. doi:10.1109/WiCom.2008.1805

Yang, X.-p. & Gao, P. (2011, May). A quantitative research of the time buffer of critical chain project management. *Proceedings of the 2011 International Conference on E-Business and E-Government (ICEE), May 6-8*, 1-4. Retrieved from IEEEXplore Database. doi:10.1109/ICEBEG.2011.5881320

Yoshida, S., Takahashi, H, & Goto, H. (2010, December). Modified max-plus linear representation for inserting time buffers. *Proceedings of the 2010 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), December*

7-10, 1631-1635. Retrieved from IEEEXplore Database. doi:10.1109/IEEM.2010.5674287

Zhang, J., Li, Y., & Wang, R.-x., W. (2009, September). An assembly task scheduling method for aircraft development project based on critical chain. *Proceedings of the International Conference on Management and Service Science (MASS '09), September 20-22*, 1-4. Retrieved from IEEEXplore Database. doi:10.1109/ICMSS.2009.5302562

Zhang, X., Cui, N., Bie, L., & Zuo, F. (2011, August). Buffer sizing method with considering effect of various uncertainties based on fuzzy comprehensive evaluation method in critical chain scheduling. *Proceedings of the 2011 2nd IEEE International Conference on Emergency Management and Management Services (ICEMMS), August 8-10*, 566-569. Retrieved from IEEEXplore Database. doi:10.1109/ICEMMS.2011.6015744

Zhang, Y. & Xu, Y. (2010, December). The research of multi-resource leveling optimization in critical chain management. *Proceedings of the 2010 2nd International Conference on Information Science and Engineering (ICISE), December 4-6*, 780-783. Retrieved from IEEEXplore Database. doi:10.1109/ICISE.2010.5689131

Zhao, Z. Y., You, W. Y. & Zuo, J. (2010, September). Application of innovative critical chain method for project planning and control under resource constraints and uncertainty. *Journal of Construction Engineering and Management*, *136*(9), 1056-1060. doi:10.1061/_ASCE_CO.1943-7862.0000209

Zhao, Z.-Y., You, W.-Y., & Lv, Q.-L. (2008, October). Applications of fuzzy critical chain method in project scheduling. *Fourth International Conference on Natural Computation (ICNC '08), October 18-20, 6*, 473-477. Retrieved from IEEEXplore Database. doi:10.1109/ICNC.2008.29

Zwikael, O. (2009, December). The relative importance of the PMBOK® Guide’s nine knowledge areas during project planning. *Project Management Journal*, *40*(4), 94-103. doi:10.1002/pmj.20116 (45361826)

Zwikael, O., Cohen, Y., & Sadeh, A. (2006, May). Non-delay scheduling as a managerial approach for managing projects. *International Journal of Project Management*, *24*(4), 330-336. doi:10.1016/j.ijproman.2005.11.002

APPENDIX A

LIST OF ACRONYMS

ATE = Automatic Test Equipment (department at Boeing in St. Louis)

CCPM = Critical chain project management

CEO = Chief Executive Officer

CIT = Critical Incident Technique

CPM = Critical path method

CS = Chi-squared analysis

CSF = Critical success factor

EVM = Earned Value Management

IP = Internet Protocol

MW = Mann-Whitney Test

NPD = New product development

PMBOK® = Project Management Body of Knowledge

PMI = Project Management Institute

S&T = Strategy and Tactics (as part of the Theory of Constraints Strategy and Tactics Tree)

SCoP = Scheduling Community of Practice (part of the Project Management Institute)

TOC = Theory of Constraints

WBS = Work breakdown structure

WIP = Work-in-process

APPENDIX B

CRITICAL CHAIN CONCEPTS

Critical chain project management (CCPM) was introduced to combat issues that plague projects under the use of the traditional critical path method (CPM), namely that on-time project completion, despite efforts to include safety time (contingency included in each task[10] estimate), is difficult (Goldratt, 1997). The discussion that follows about CCPM concepts does not seek to replicate the structured process of CCPM in its entirety, but instead seeks to highlight the features of CCPM while also highlighting some of the advantages of CCPM over CPM. Before beginning the discussion, the definitions as included in the literature review are repeated below:

- The *critical path* is the longest link of sequential tasks that determines a project's completion date on a schedule, where delays in the critical path will delay the whole schedule (Project Management Institute, 2008).
- *Critical path method* (CPM) is the method used for planning, monitoring, and controlling the schedule based on the established critical path (Project Management Institute, 2008).
- The *critical chain* is the longest link of sequential tasks taking into consideration resource constraints (not necessarily true for the critical path) where the project's completion date is determined only after a project buffer has been added to the end of the critical chain (Project Management Institute, 2008).
- *Critical chain project management* (CCPM), as coined by Leach in 1998, is the project schedule planning, monitoring, and controlling method that uses the critical chain, first

[10] Task and activity are synonymous. Task will be used instead of activity throughout and refers to an assigned activity or task (usually in a sequence) that a project worker (resource) needs to complete.

for schedule planning by establishing the critical chain and buffers and then for monitoring and controlling the project schedule in terms of the buffers (Leach, 2005).

Removing Safety Time from Critical Chain Activities

Following the establishment of project tasks (system constraints) using the guidance of the work breakdown structure (WBS), attributes of each of the tasks (such as precedence relationships, estimated durations, and resource requirements) are used to develop the critical chain. As defined above, the critical chain is identified as the longest sequence of tasks that takes into account resource constraints. However, estimating task duration is the first source of problems for on-time completion using CPM that CCPM seeks to address. Using CPM, the system requires that a single estimate of duration is assigned for each task such that all work for that task is completed within the duration specified. Ultimately, that single estimate must account for all the potential risks involved in the task leading to a final duration estimate that is longer than originally intended. If deviation in task duration occurs and no contingency time has been added in the original estimated duration, then that task will be delivered late. People working within this system estimate their work in terms of how long it will take to safely complete the project task because the project worker (resource) does not want to risk a poor reputation by completing the task late (Goldratt, 1997). The project resource knows that the estimate will be used to establish a schedule and once the schedule is established, he/she will have a firm due date in which to complete the task. Knowing this ahead of time, the project resource gives an estimate with some safety time (contingency) included (Goldratt, 1997, p. 117). In environments where the project resource is not able to dedicate focused effort towards a task, the need for multitasking will also be a consideration when developing the initial estimate (Goldratt, 1997, p. 117). This will result in more added safety time for that individual task (Goldratt, 1997, p. 117).

Working within this same CPM system, the supervisor of the project resource receives the estimate and adds additional safety time, reasoning that if the project worker does not complete the task on time, this will reflect poorly on the supervisor (Goldratt, 1997, p. 117). Regardless of when the schedule (tasks sequenced together) is built using the estimates, the estimate for each task will generally increase with each management review until the schedule reaches the highest management review level (Goldratt, 1997, p. 118). At this level, the schedule is too long (with all the added safety time) and an arbitrary percentage of schedule duration is cut, such as 20% (Goldratt, 1997, p. 118). Knowing that the highest management level will cut the task durations reinforces the behaviors described above, resulting in even more safety time initially included for each task (Goldratt, 1997, p. 118). VanOverloop and Peterson (2009) provided an illustration, shown below in Figure B-1, of safety time (padding) that is included in initial task durations.

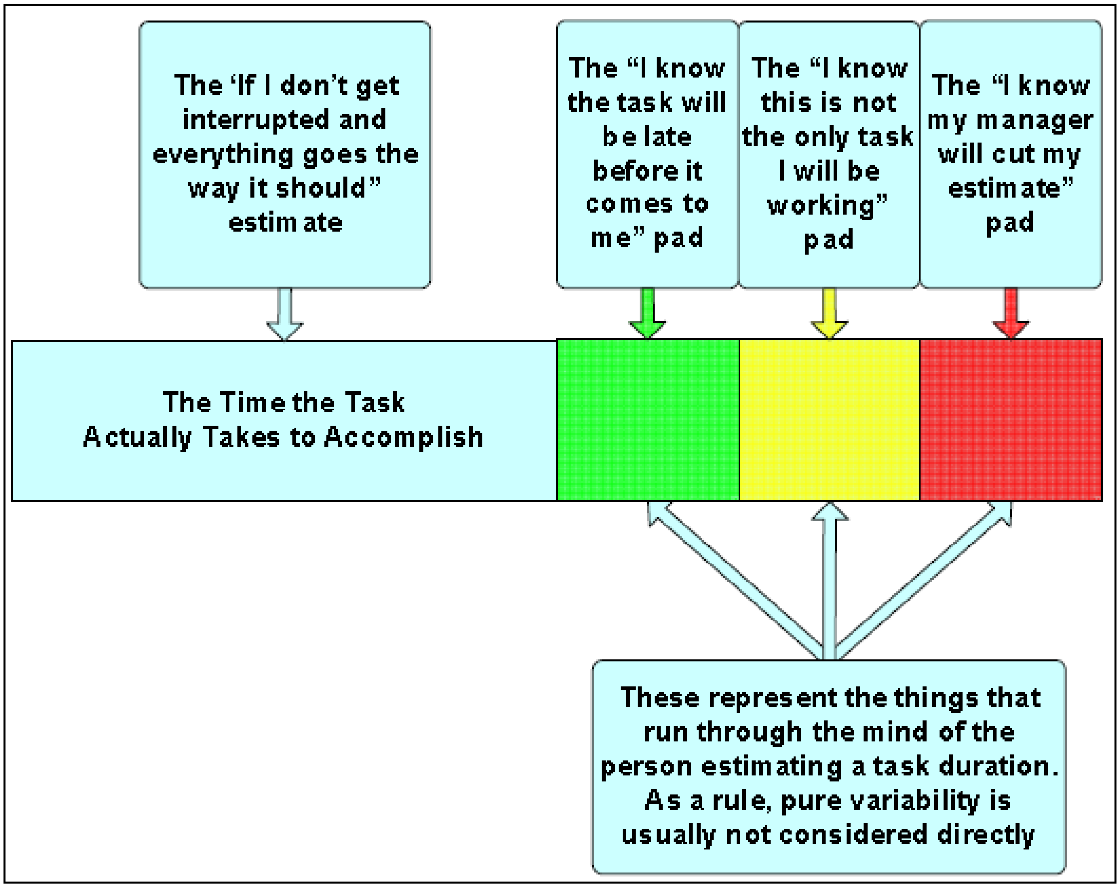

Figure B-1. VanOverloop and Peterson (2009) illustrated how safety time (padding) is added into original task duration estimates (p. 1).

Once a CPM schedule is finalized, there is plenty of safety time included in each task, so the project as a whole should be easily completed by the scheduled deadline, right. Many times this is not the case because the safety time that is included in each task is completely used (or wasted) with the passing of each task on the project schedule (Goldratt, 1997). All of the allotted time for each task is used before the work is passed to the next resource (Parkinson's Law[11]); unexpected events that are beyond the resource's control caused delays (Murphy's Law[12]); resources procrastinate and do not start a task until closer to the deadline

[11] Parkinson's Law for project tasks refers to a condition in which the resource uses all the safety time even though it is not needed (Casey, 2005, p. 90)
[12] Murphy's Law is typically understood as "anything that can go wrong, will go wrong" and for project tasks refers to special-cause variation where unexpected circumstances cause the task to

(Student Syndrome[13]); resources multitask and as a result use safety time; or resources fail to report early finishes (Casey, 2005; Goldratt, 1997; Robinson & Richards, 2009). The latter occurs for the following three reasons: (1) to prevent safety time from being cut in the future for similar tasks, (2) to maintain credibility since this same resource provided the original estimate, and (3) due to the knowledge that the next task is not ready or scheduled to begin (Casey, 2005; Goldratt, 1997; Robinson & Richards, 2009).

Multitasking is one of the more elusive ways in which safety time is used inefficiently because people are busy and also believe that they are working as efficiently as possible on each task. In reality, most tasks would finish sooner if focused work on each task was used instead. Goldratt (1997) explained the downfalls of multitasking using the visual provided in Figure B-2 below (p. 126). A project resource is assigned three tasks to complete (A, B, and C), where each individual task takes ten days to complete (Goldratt, 1997). To show progress on each task, the resource decides to multitask and complete half of each task in the order A, B, and C before returning back to finish each of the tasks in the same order (Goldratt, 1997). By multitasking, the project resource completes task A on day 20, task B on day 25, and task C on day 30 (Goldratt, 1997). If instead the project resource decided to focus on each of the tasks until completed in the order A, B, and C, then A would be finished on day 10, B would be finished on day 20, and C would be finished on day 30 (Goldratt, 1997). Multitasking caused A to be finished 10 days later than necessary and B to be finished 5 days later than necessary, while C was finished on the same day (Goldratt, 1997, p. 126).

---

go longer than expected (Leach, 2001, p. 48). Alternately, common-cause variation is variation that occurs within the expected control limits of the task duration (Leach, 2001, p. 48).

[13] Student Syndrome for project tasks refers to a condition in which the resource has plenty of time to complete the task but does not start the task until closer to the deadline (Casey, 2005, p. 90). If problems (or variations) occur once the resource has started the task late, then there is no remaining safety time in which to complete the task before the deadline (Casey, 2005, p. 90).

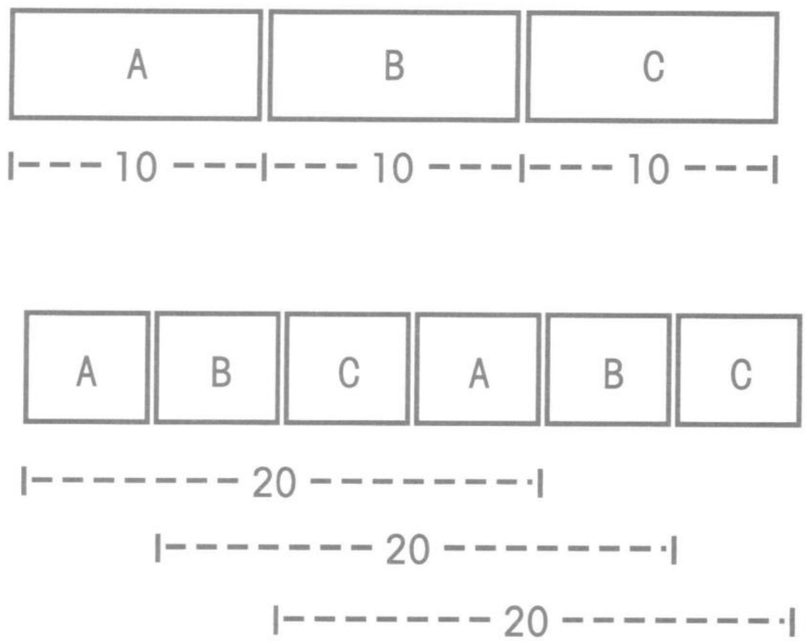

Figure B-2. Goldratt (1997) illustrated how multitasking affects task completion (p. 126).

Figure B-2 demonstrates the time that is used inefficiently multitasking in comparison to completing tasks one at a time in a focused manner. However, there are also additional efficiency losses due to multitasking (Goldratt, 1997). Each task requires set up time and a mental transition; so every time a resource switches from one task to another, additional time is used that is not accounted for in the schedule (Goldratt, 1997). With increases in the use of multitasking, there are increases in the time lost in efficiency due to switching between tasks (Goldratt, 1997). Even if the disadvantages of multitasking are understood, resources still believe there is a need to multitask because they are "under pressure and [try]…to satisfy everybody" (Goldratt, 1997, p. 126).

CCPM addresses issues in wasted or used safety time, especially for time lost due to multitasking. CCPM, as a system, creates a backdrop where multitasking is not necessary and even strongly discouraged. For CCPM, safety time (contingency) is not included in each individual task and is instead pooled (at a reduced level) at the end of a CCPM schedule. Each individual task estimate in a CCPM schedule is determined using a 50% completion level estimate (based on the median completion time for this distribution) where 50% of the time the task can be completed in the duration estimated and 50% of the time the task cannot be completed within the specified duration (Leach, personal communication, February 17, 2012). Casey (2005) defined this as “the aggressive-but-possible estimate” and “the duration that would occur if all the required resources—parts, personnel, engineering drawings, etc.—are available when needed and the resource (or work group, if applicable) is allowed to focus entirely on this task” (p. 85). Therefore, each task within a CCPM schedule essentially has no safety time built into its duration estimate when compared to an equivalent duration estimate in a CPM schedule (Goldratt, 1997).

When implementing in the traditional work environment, resources may not be comfortable estimating 50% (median) completion probabilities, so an arbitrary cutting of the task estimates in half is suggested (Goldratt, 1997, p. 156). Along with changing the way estimates are established, there is a change in the way work is conducted from working to meet a deadline (CPM) to working to complete one task at a time as efficiently as possible (CCPM) (Goldratt, 1997). Patrick (1999a) noted that safety time can only be eliminated “when resources trust management and project owners to accept that activities’[/tasks’] target durations are not commitments” (p. 62). In CCPM, the project resource does not have to meet a deadline for a task; instead the project resource needs to focus on only that task, complete that task as quickly as possible, and pass that task to the next resource in the schedule upon completion.

These reduced task durations without safety time included are sequenced together to form an initial baseline critical chain schedule (the “critical chain”). The critical chain takes into account resource constraints, meaning that the same resource is not scheduled for two tasks at the same time. This is a deterministic process and can be conducted for CPM tasks that include safety time as well.

Insertion of Buffers to Create the Baseline Critical Chain Schedule

Now that all the safety time is removed and the critical chain is established, how is the project protected from uncertainty? The estimated completion times for each task are not time commitments but instead are used in CCPM as a way determine a “high-probability completion date for the project” after the addition of a pooled buffer (project buffer) placed at the end of the CCPM schedule (Leach, personal communication, February 17, 2012). Normal variability will still occur within expected control limits for each task’s duration, referred to as common-cause variation (Leach, 2001, p. 48). Deviations up or down from estimated completion times due to common-cause variation will either add to or subtract from the project buffer. In this way, the project is protected from uncertainty caused by common-cause variation (Leach, personal communication, February 17, 2012). The estimated completion times also provide a means by which to “prioritize the tasks during execution” based on buffer penetration (Leach, personal communication, February 17, 2012). In measuring buffer penetration, common-cause variability in task duration is expected and will not require management attention (Leach, 2001, p. 48). Special-cause variation that occurs, circumstances that cause the task duration to deviate out of the expected control limits, may require management intervention (Leach, 2001, p. 48). This will be explored in more detail below, along with buffer management.

Goldratt (1997) suggested when transitioning from a critical path schedule to a critical chain schedule, where task durations on the critical chain were reduced by 50%, that the amount of safety time removed should be halved and relocated to the end of the critical chain in the form of a project buffer (Goldratt, 1997, p. 156). Positioning the buffer in this way allows the project manager to assign contingency for uncertainty that will only be used as needed through the course of the project, instead of being inefficiently used the individual task level for the reasons described above (Goldratt, 1997). The total schedule for one project is determined by the critical chain and project buffer put together. This is typically shorter than the same project scheduled using the CPM (Goldratt, 1997). Leach (2011) stated that "critical chain schedules, including the project buffer, are usually about 25% shorter than resource-leveled critical path schedules" (p. 6).

Besides the project buffer, other buffers are also inserted in the baseline critical chain schedule to protect the critical chain from additional uncertainties. These include feeding buffers, resource buffers, capacity buffers, drum buffers, and milestone buffers as described below.

- The feeding buffers protect the non-critical tasks from impeding progress on the critical chain; they allow all non-critical tasks to be scheduled on a late-start basis (as opposed to starting non-critical tasks at the beginning of a project on an early start basis) with the feeding buffer positioned between the non-critical tasks and their intersections with the critical chain (Goldratt, 1997).
- The resource buffers ensure that critical resources are informed when they are part of an upcoming critical chain task so the resource can begin promptly when the previous task is completed (Goldratt, 1997). The resource buffer does not prolong the schedule as a time buffer and is instead used for enhancing communication about anticipated completion of predecessor tasks (Goldratt, 1997). Leach noted that "most current applications of CCPM use a prioritized list instead of a resource buffer" (personal communication, February 17, 2012).

- Capacity buffers are used in a multi-project environment for staggering/pipelining projects and are not added to individual critical chain schedules. Lechler et al. (2005b) stated, "Capacity buffers are introduced to ensure that performance on one project does not delay the promised due date on another project…[and] represents a 'time delay' between the completion of work by the bottleneck[/drum] resource on one project and the beginning of its work on the succeeding project" (p. 54).
- The drum buffer is used in a multi-project environment to ensure that all previous tasks ahead of a drum/bottleneck resource (a resource that is part of more than one critical chain) are completed to ensure efficient use of the drum resource's time (Leach, 1998). This buffer makes it possible for a critical chain schedule (such as Project B's critical chain schedule) to take advantage of the drum resource's early completion of a task in a different project (such as Project A) (Leach, personal communication, February 17, 2012). The drum buffer is placed in an individual project's (Project B's) critical chain schedule between preceding critical chain tasks and the drum resource's critical chain task (this will make the dates of the preceding critical chain tasks start earlier than if the buffer were not inserted). Leach noted that this buffer has "turned out to be unnecessary and confusing" (personal communication, February 17, 2012).
- Lechler et al. (2005a) also referred to an additional milestone buffer that is used to protect intermediate milestones in a project (Slide 22). Lechler et al. (2005a) stated, "milestone buffers were placed in front of all contractual milestones [dates] and were 50% of the 'local' critical chain" (Slide 22). Leach noted that these buffers are for initial planning purposes to set milestone commitment dates if needed and are not added into individual critical chain schedules (personal communication, February 17, 2012). In the critical

chain schedule, a milestone may fall between tasks in the critical chain but work continues on the critical chain uninterrupted once the milestone (based on task completion) is reached (personal communication, February 17, 2012).

All of the buffers discussed above, with the exception of the milestone buffer, are shown below in Figure B-3. As shown in the figure, drum buffers are differentiated from capacity buffers because drum buffers are inserted into the individual critical chain schedules, whereas capacity buffers are used for spacing the staggered/pipelined projects in a multi-project CCPM environment. Feeding buffers are inserted into paths that feed the critical chain for each project and project buffers are inserted at the end of the critical chain schedules.

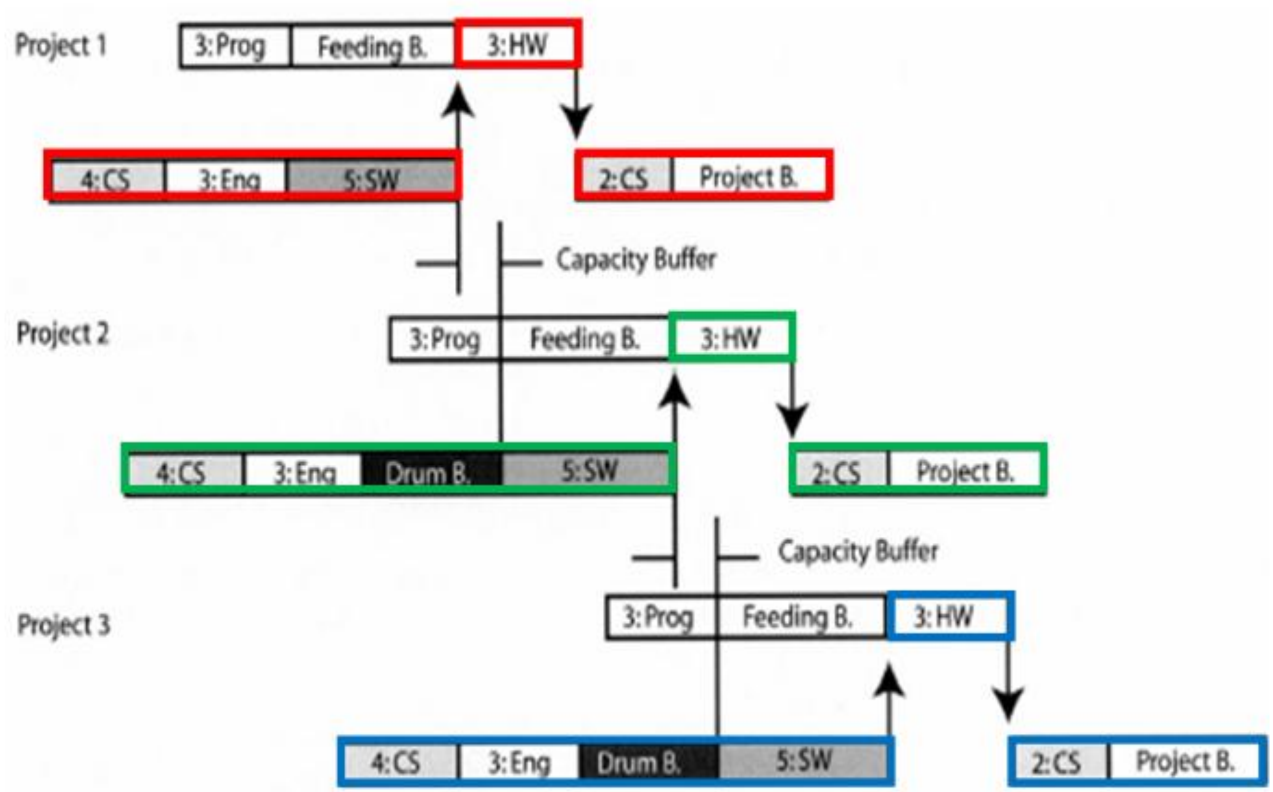

Figure B-3. Lechler et al. (2005b) illustrated project, feeding, drum, and capacity buffers in a multi-project CCPM environment (p. 54). *Task notation appears in the form of estimated time units: resource. SW is the bottleneck/drum resource. Red, green and blue represent the critical chain for projects 1, 2, and 3, respectively. "B." represents the word "buffer."*

Monitoring and Controlling Critical Chain Projects using Priorities and Buffer Management

CCPM establishes project priorities at all levels in the organization. In multi-project environments, the constraining drum resource(s) are determined and individual projects are prioritized and staggered/pipelined according to these resources (Leach, 1998). Leach noted that many now use what is referred to as a “virtual drum” to stagger/pipeline projects by using a variety of methods to “set a limit on the number of active projects” (personal communication, February 17, 2012). The project manager can manage individual projects according to performance of the critical chain and tasks feeding into the critical chain by monitoring buffer consumptions determining how an individual project is progressing (Goldratt, 1997). The individual project team members know the priority of all assigned tasks. If a project team member is working on a task that will have an impact on the project buffer, he/she understands the need to devote 100% of their attention to that task so that the succeeding task can begin as soon as possible (Goldratt, 1997). If a project team member is not working on a task that can potentially impact the project buffer, he/she knows which tasks have the highest priority in relation to the project buffer by using the priority task list (Leach, 2005). Part of prioritizing appropriately at all levels in the organization is changing behavior from the due-date mentality toward focusing on completing single tasks as quickly as possible (Goldratt, 1997).

In the traditional CPM, priorities are not always clear. For instance, the sharing of resources across projects in a multi-project environment is not well-planned and the priority of projects may not be fully understood by upper management, project managers, and project team members that work on multiple projects (Homer, 1998). Additionally, all non-critical path tasks are usually early-start (left-shifted), diverting the project manager’s attention away from the critical path at the beginning of the project (Goldratt, 1997). Finally, individual resources have multiple tasks to divide their attention including possible non-project work and must determine their own priorities in completing all assigned tasks (Goldratt, 1997). Another drawback to using CPM is that tasks are rarely reported as completed early and instead are either on-time or late for reasons discussed earlier in Appendix B. This results in the need for continual contingency planning to keep the project on schedule and may include one of the following actions: increasing cost to "crash" or speed-up parts of the schedule, sacrificing quality, surrendering scope, and/or rescheduling the critical path (Goldratt, 1997). Cervany and Galup (2002) articulated that "the challenge has always been distinguishing between those tasks that are experiencing normal variability and those tasks that require intervention [and]…with the current modes of project management [CPM], that distinction cannot be made" (p. 61).

The solution to giving the appropriate amount of attention to tasks is the use of buffer management to monitor and control the schedule through the use of CCPM (Leach, 1998). Patrick (2001) emphasized, "Buffer management is the key critical chain process for monitoring and controlling projects. It provides the basis for ongoing awareness of changing risk and guidance for when that risk suggests a need for action" (p. 3). A fever chart (with green/yellow/red distinctions) is used to depict the relationship between the percentages of the project buffer consumed to percentages of the critical chain completed (Leach, 1998). Buffer penetration in the green level is no cause for concern and can be attributed to common-cause variation (Leach, 1998; 2001). Buffer penetration that can be attributed to special-cause variation, causing the buffer to be penetrated beyond the normal control limits, requires investigation and action planning. Buffer penetration in the yellow section draws attention to the critical chain tasks and requires the formation of a plan to recover some of the lost buffer (Leach, 1998). Buffer penetration into the red zone triggers execution of the plan that was established when in the yellow zone (Leach, 1998). Leach (2011) provided an example fever chart used for single-project buffer management in Figure B-4.

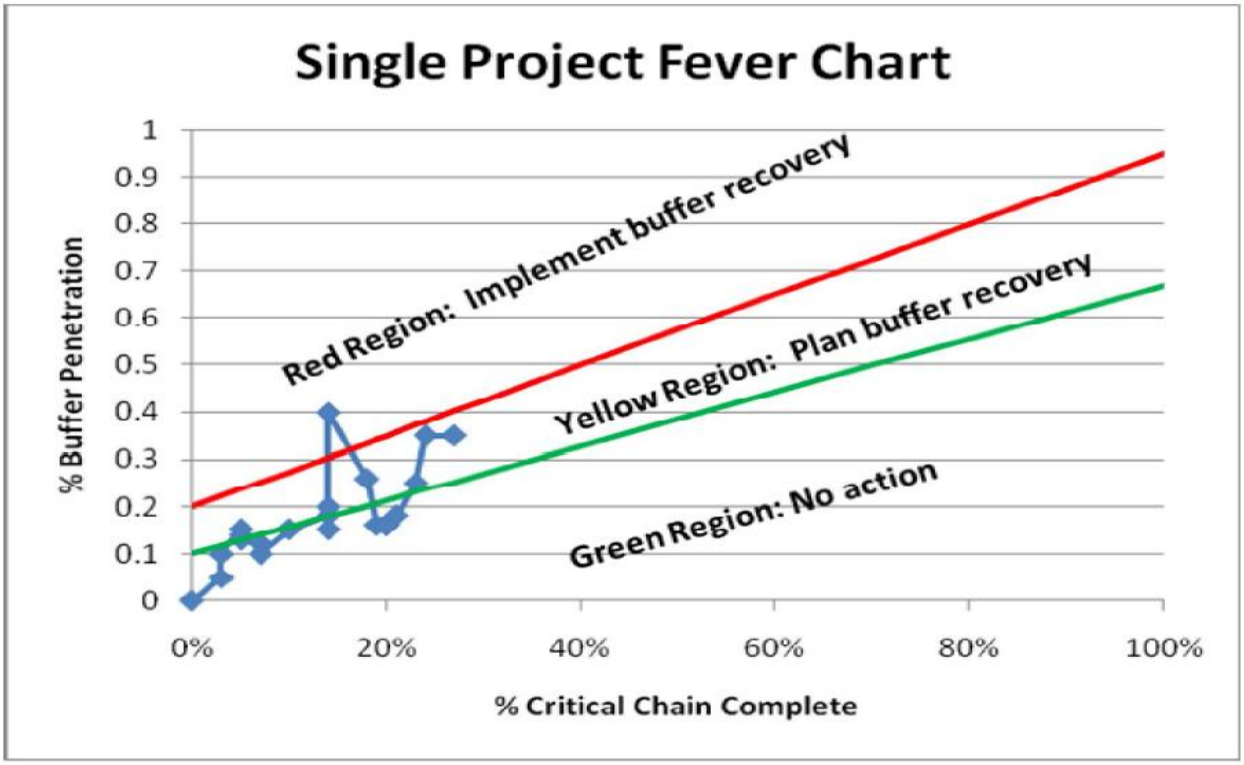

Figure B-4. Leach (2011) provided a buffer management fever chart (p. 9).

CCPM Foundation

Exploring the foundation of CCPM is now possible with a greater understanding of how CCPM works. Goldratt (1997) derived what is now referred to as CCPM from the Theory of Constraints (TOC) which was first mentioned by Goldratt in 1984 with the publication of *The Goal*. Figure B-5 below relates how CCPM follows TOC's five-step process (Yang, 2007, p. 26). Once fully implemented, CCPM continues to repeat the steps as described below, as in TOC, to create a continuous improvement cycle.

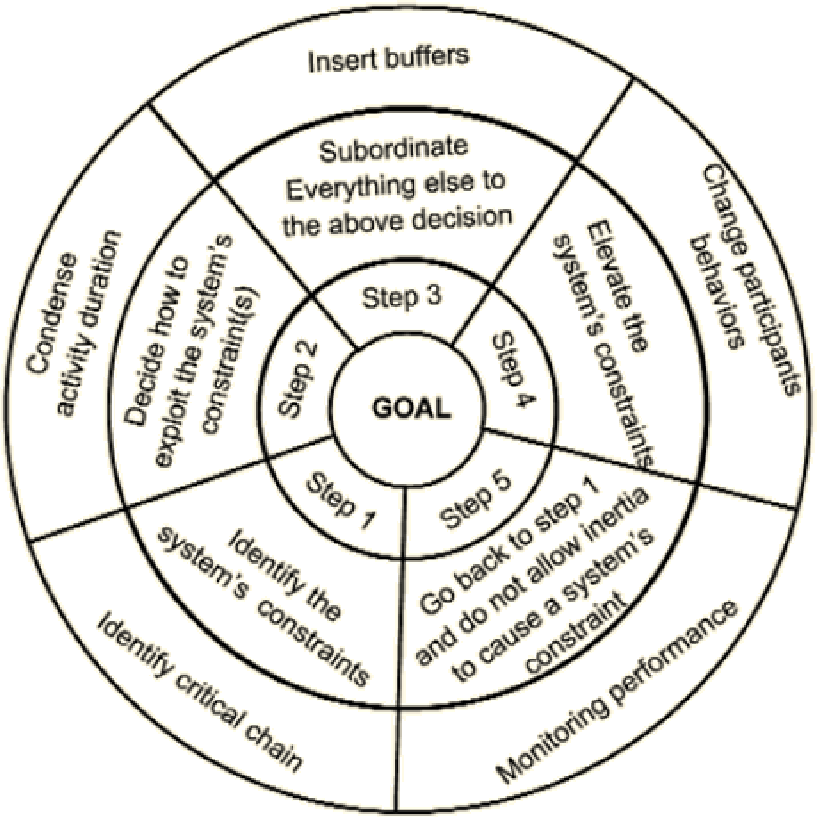

Figure B-5. Yang (2007) illustrated the relationship between the Theory of Constraints and critical chain concepts (p. 26).

Each of the five TOC steps relating CCPM as shown in Figure B-5 above can be further clarified.

1. Part of identifying the critical chain is realizing that a resource-leveled schedule needs to be used for the critical chain to alleviate the system constraints.
2. Exploiting the constrained resources requires that each task needs to have all extra contingency time removed. Condensing task durations is possible because resources will be enabled to focus on one task at a time instead of multitasking.
3. Adding buffers to the baseline critical chain schedule cements the plan for the project team around the constrained resources to create a realistic, achievable schedule that has contingencies pooled at the end of task sequences.

4. Lechler et al. (2005) provided additional clarification for this step: “Elevation of the constraint…depends on the decision-makers to add more capacity to the systems constraint” (p. 49). This involves the process of reviewing the schedule and making decisions that will help to alleviate current constraints, such as adding resources for a critical task to complete that task more quickly. This can be a behavioral change for decision makers involved in the CCPM process.
5. With instructions to go back to Step 1, step 5 creates a continuous improvement loop using buffer management “provided that improvement opportunities are continuously identified and properly prioritized” (Realization, 2006).

Summary of Critical Chain Concepts

Appendix B has addressed the basic concepts surrounding the use of critical chain project management (CCPM). Contingency is not included in individual tasks as part of the CCPM schedule. Instead, tasks are sequenced into a resource-constrained schedule and buffers are inserted to protect the schedule from uncertainties present in task duration estimates. The following buffers have been identified for use in CCPM: project buffers, feeding buffers, capacity buffers, resource buffers, drum buffers, and milestone buffers. The priority task list is used to aid project team members in the completion of tasks in the most efficient manner, while project team members work on single tasks one at a time without multitasking. Buffer management is used to alert the project team that variation between actual and estimated completion times is no longer attributable to common-cause variation and requires management planning and/or action to recover lost buffer time. Finally, CCPM is derived from the Theory of Constraints (TOC) and follows its five steps to create a continuous improvement cycle.

APPENDIX C

SURVEY

Survey Name: Critical Chain Implementation Factors

(PAGE 1)
WELCOME!
Hello and welcome to the Critical Chain Implementation Factors survey! My name is Lisa Repp and I am a graduate student completing a master of science degree in project management at the University of Wisconsin-Platteville. I will be using this survey for analysis in my master's thesis, *Factors that Influence Critical Chain Project Management Implementation Success.*

Factors included in the survey have been derived from an extensive review of literature. The results from the survey will be analyzed to determine which factors are influential in the success (or failure) of critical chain implementations. This type of structured comprehensive assessment has not been completed for critical chain implementations and your participation in this survey will directly impact the quality of the research results.

The survey takes approximately 20 minutes. While this is a significant amount of your time, please consider the following personal benefits you receive by completing the survey:

(1) you will see firsthand what potential factors have been identified in literature that can influence the success rate of CCPM implementations and
(2) upon completion of the survey you will be given a link to view all survey results.

Your survey answers are completely anonymous. Please do not enter your name or the name of the organization you are associated with anywhere on the survey. All questions are required (denoted with an *) except for the last optional question.

Thank you so much for choosing to participate. If you know of anyone else that has critical chain implementation experience, please forward the survey link to them as well. Comments or questions can be entered at the end of the survey. Alternatively, I can be contacted directly via email at lisamrepp@yahoo.com. Please also consider contacting me via email to participate in a follow-up interview to share your personal experiences with a successful, less successful, or failed critical chain implementation.

Sincerely,
Lisa Repp

CONFIDENTIALITY STATEMENT: The survey responses are completely anonymous and the information gathered in this study will be used for a thesis research paper and summary research paper for publication. The survey data will be kept in a file on a password protected computer.

(PAGE 2)
Survey Access Point

*How did you access this survey? (select one)
- o PMI Survey Link
- o Link posted in PMI Scheduling Group
- o Link posted in CriticalChain Yahoo! Group
- o Link posted in LinkedIn CriticalChain Group
- o Forwarded in an email from critical chain software supplier
- o Forwarded in an email from contact in professional network
- o Other: ________________________________

(PAGE 3)
Experience in a Project Organization
Please complete the following survey, keeping only one experience in mind throughout. Feel free to return to the survey for a separate position/experience.

*What is your position (or previously held position) in relation to an organization completing projects? (check all that apply)
- □ Work(ed) on project tasks (project team member or project resource)
- □ Manage(d) individual projects (project manager)
- □ Functional (department) manager with subordinates that work(ed) on project tasks
- □ Manage(d) a portfolio of projects (program manager)
- □ Upper management (to which the project manager or program manager report(ed) project progress)
- □ Senior management of an organization completing projects
- □ Management consultant (external to project organization, providing guidance on managing projects)
- □ External supplier/contractor/sub-contractor for an organization completing projects
- □ No association with an organization that completes projects

(PAGE 4)
Critical Chain Concepts
Definitions:
Critical Chain**:** *The critical chain is the longest link of sequential activities taking into consideration resource constraints where the project's completion date is determined only after a project buffer has been added to the end of the critical chain.*
Critical Chain Project Management (CCPM)**:** *Project schedule planning, monitoring, and controlling method that uses the critical chain for schedule planning by first establishing the critical chain and buffers and then for monitoring and controlling the project schedule in terms of the buffers.*

*What is your familiarity with critical chain concepts as applied to the project environment? (select one)

- Unfamiliar with the critical chain concepts <ends survey>
- Knowledgeable but have no experience related to critical chain concepts (go to page 5)
- Knowledgeable and have experience related to critical chain concepts (go to page 6)

(PAGE 5)
Critical Chain Experience
Definitions:
<u>Critical Chain</u>: *The critical chain is the longest link of sequential activities taking into consideration resource constraints where the project's completion date is determined only after a project buffer has been added to the end of the critical chain.*
<u>Critical Chain Project Management (CCPM)</u>: *Project schedule planning, monitoring, and controlling method that uses the critical chain for schedule planning by first establishing the critical chain and buffers and then for monitoring and controlling the project schedule in terms of the buffers.*

*Please complete the following statement: I am knowledgeable about critical chain concepts but do not have any experience related to the concepts because…(check all that apply)

□ there is no relationship between the critical chain concepts and my job. <ends survey>
□ the project organization that I am associated with has not implemented the concepts. <ends survey>
□ I (or the project organization that I am associated with) investigated implementing critical chain concepts but decided not to pursue implementation. <ends survey>
□ I am (or the project organization that am associated with is) currently investigating implementing critical chain concepts. <ends survey>
□ I learned about critical chain concepts for its current implementation in the project organization I am associated with but have not used the critical chain concepts yet. <ends survey>
□ Other <ends survey>

Please add additional clarifying comments related to your selection(s) above.

____

(PAGE 6)
One Specific Critical Chain Implementation Experience
Please recall your personal experience with the implementation of critical chain concepts related to **only one specific event** in answering the remainder of the survey questions.
(Participants are encouraged to fill out the survey more than once if they have been involved in separate CCPM implementations.)

Definitions:
Single-project CCPM implementation *utilizes critical chain concepts for schedule planning, monitoring, and controlling for an individual, stand-alone project.*
Multi-project CCPM implementation *involves the staggering of projects based on the constrained resource(s) shared between projects, while also using critical chain concepts for schedule planning, monitoring, and controlling for each individual project in the multi-project system.*

*The following statement best describes my personal experience related to **one specific** critical chain project management (CCPM) implementation event. (select one)
- I have no experience related to the implementation of critical chain concepts. (go to page 7)
- I was a participant in a single-project CCPM implementation. (go to page 8)
- I was a participant in a single-project CCPM implementation as a pilot test for a future multi-project implementation. (go to page 8)
- I was a participant in a multi-project CCPM implementation that followed a single-project CCPM implementation pilot test. (go to page 8)
- I was a participant in a multi-project CCPM implementation.(go to page 8)
- Other:____ (go to page 8)

(PAGE 7)
Critical Chain Experience
Definitions:
Critical Chain: *The critical chain is the longest link of sequential activities taking into consideration resource constraints where the project's completion date is determined only after a project buffer has been added to the end of the critical chain.*
Critical Chain Project Management (CCPM): *Project schedule planning, monitoring, and controlling method that uses the critical chain for schedule planning by first establishing the critical chain and buffers and then for monitoring and controlling the project schedule in terms of the buffers.*

*Please describe your experiences related to critical chain.
- Prefer not to answer <ends survey>
- Description of experience: ____ <ends survey>

(PAGE 8)
Pre-existing Conditions in Relation to the Critical Chain Implementation Experience
CCPM = critical chain project management
Reminder: answer the questions in relation to the one specific implementation event you had in mind for the previous question. However, please feel free to take the survey again for separate CCPM implementation events.

*In what industry was the one specific critical chain project management (CCPM) implementation event?

- Software
- Communication
- Services
- Government
- Construction and Engineering
- Production
- Other: ______________

*Is there a project management office (PMO) in the organization that implemented CCPM?

- Yes
- No
- Don't Know

*How many people are there in the project organization that implemented CCPM?

- 0 – 100
- 101 – 500
- 501 – 2,500
- 2,501 – 5,000
- More than 5,000
- Don't Know

(PAGE 9)

Pre-Implementation Organizational Information

Please provide a snapshot of what the project organization you are (were) associated with before implementing critical chain project management (CCPM) in terms of the following areas:

* Rate the level of concern for each of the following in terms of the organization's project focus **before** implementation of CCPM using the star rating scale.

1 star (no concern)....2-10 stars (degrees of increasing concern)....11 stars (of primary concern)

Focus on completing projects on schedule Ø***********

Focus on completing projects within budget Ø***********

Focus on completing projects within scope specifications Ø***********

Focus on completing projects of high quality Ø***********

Please provide any clarifying comments as needed.

---

*Rate each of the following for their usage in the organization **before** implementation of CCPM using the star rating scale.

1 star (not used)....2-10 stars (degrees of increasing usage)....11 stars (significant usage)

Standard project management practices for planning and execution of projects Ø***********

Network-based scheduling techniques Ø***********

Schedule monitoring/control using critical path
(task sequence that determines length of project) Ø***********

Collection of time and cost tracking data Ø***********

Please provide any clarifying comments as needed.

---

*What were the levels of uncertainty involved in estimating project task durations when developing an initial project schedule in the organization?

- Extremely Uncertain
- Moderately Uncertain
- Moderately Certain
- 100% Certain
- Don't Know

*Typical projects in the organization have how many estimated activities associated with initial project schedules?

1. 0 – 400 estimated activities/tasks per project
2. 401 – 800 estimated activities/tasks per project
3. 801 – 1,200 estimated activities/tasks per project
4. More than 1,200 estimated activities/tasks per project
5. Projects in which number of activities/tasks varies too much to be estimated
6. Don't know

(PAGE 10)
Critical Chain Implementation Goals
CCPM = critical chain project management

*Below are potential benefits from CCPM implementation. Rate the level of concern for each of the following in terms of the **organization's goals when pursuing CCPM implementation** using the star rating scale.

1 star (no concern)....2-10 stars (degrees of increasing concern)....11 stars (of primary concern)

Try something new that other organizations are having success with	Ø***********
Complete project(s) faster	Ø***********
Increase project throughput	Ø***********
Increase on-time delivery percentage for project(s)	Ø***********
Increase quality on project(s)	Ø***********
Minimize scope changes for the project(s)	Ø***********
Minimize cost increases for the project(s)	Ø***********
Ability to better prioritize the projects and/or project tasks	Ø***********
Better way to manage project resources	Ø***********
Reduce stress in the work environment	Ø***********
Increase the chance(s) that the project(s) will be completed	Ø***********
Reduce the amount of work-in-progress (inventory)	Ø***********
Minimize the need for multitasking by project resources	Ø***********
Speed up a new product introduction into the market	Ø***********
Ability to charge premiums for faster project completions	Ø***********
Financial benefits that will affect the organization's bottom line	Ø***********

Additional goals or clarifying comments:____

(PAGE 11)

Degree of Critical Chain Implementation Success

Reporting the success rate of critical chain project management (CCPM) implementation can be based on measurements of a feeling of success/satisfaction on meeting the intended goals/expectations when pursuing CCPM implementation.

*Please rate the level of success of the CCPM implementation on the star rating scale.

1 star (no success)....2-10 stars (degrees of increasing success)....11 stars (extremely successful)

CCPM implementation success. Ø***********

Review each of the statements about CCPM implementation success and check all that apply.

- ☐ The organization (or project) is in a worse position than before due to the CCPM implementation.
- ☐ If CCPM had not been implemented, the organization (or project) would be in the same position.
- ☐ Only some of the intended CCPM implementation goals were met.
- ☐ All of the intended CCPM implementation goals were met.
- ☐ The intended CCPM implementation goals were met and exceeded.
- ☐ CCPM implementation was able to contribute financially to the organization’s bottom line.
- ☐ Other

Additional clarifying comments: ____

(PAGE 12)
Extent that Critical Chain Features were Implemented
CCPM = critical chain project management

*Below are the features of CCPM. Please evaluate the degree of implementation for each feature using the star rating scale.

1 star (not implemented).2-10 stars (degrees of increasing implementation).11 stars (full implementation)

Clear definition of scope for project(s)	Ø***********
Average work required and resource requirements assigned for each task in schedule	Ø***********
Reduced task duration estimates at 50% probability of completion	Ø***********
Clear definition of baseline critical chain	Ø***********
Project buffer (buffer between critical chain and scheduled project completion date)	Ø***********
Feeding buffers (buffers between non-critical feeding chains and critical chain)	Ø***********
Resource buffers (used to communicate prerequisite task completion for upcoming resource)	Ø***********
Milestone buffers (used ahead of project milestones)	Ø***********
Drum buffers (used ahead of critical shared resources in a multi-project environment)	Ø***********
Capacity buffers (used for pipelining/staggering projects)	Ø***********
Projects in a multi-project environment are deliberately staggered/pipelined	Ø***********
Buffer management is used to monitor and control projects on at least a weekly basis	Ø***********
Buffer management used to plan and act on recovering buffer when needed	Ø***********
Remaining task duration used when reporting status on project tasks	Ø***********
Rescheduling of the critical chain used as the exception and not the rule	Ø***********
Environment created that minimized the need for multitasking	Ø***********
Project team members understood task priorities (priority task list)	Ø***********
Highest priority tasks completed as quickly as possible and given to next resource without delay	Ø***********
Integration of contractors/suppliers into CCPM taken into account during project planning	Ø***********

Additional features or clarifying comments: ___________________________

(PAGE 13)
Presence of Factors that can be Attributed to Changing Behavior
CCPM = critical chain project management

*Below are the factors that potentially impact the success rate of CCPM implementations in terms of the change process. Please evaluate the degree of presence for each factor using the star rating scale.

1 star (not present)....2-10 stars (degrees of increasing presence)....11 stars (significant presence)	
Buy-in initially established for CCPM	Ø***********
Buy-in maintained for CCPM throughout the process	Ø***********
Resistance to change	Ø***********
Sense of urgency	Ø***********
Champion from upper/senior management for CCPM implementation	Ø***********
CCPM champion's participation throughout the implementation process	Ø***********
Anti-champion(s) present that actively opposed CCPM implementation	Ø***********
Established vision for CCPM implementation	Ø***********
Communication about the CCPM implementation throughout the process	Ø***********
Change agents involved in the daily effort of implementing CCPM	Ø***********
Peripheral stakeholders such as customers/suppliers involved in CCPM implementation	Ø***********
CCPM software used provided the needed functionality	Ø***********
CCPM software integration into the project organization's legacy systems	Ø***********
Integration of additional roles and responsibilities for CCPM implementation	Ø***********
External consultants or experts used during CCPM implementation	Ø***********
CCPM training received adequate funding/attention from the organization	Ø***********
Basic project management concepts that support CCPM reviewed during CCPM training	Ø***********
Practical CCPM training conducted using organization's actual software and/or policies	Ø***********
Early training on the CCPM software	Ø***********
Incremental measurements used to determine CCPM implementation success	Ø***********
Measurements at the completion of the CCPM implementation used to determine success	Ø***********
The CCPM implementation process designed to give "quick wins"	Ø***********
Performance management used to reinforce CCPM behaviors (such as limiting multitasking)	Ø***********
Customization allowed (without compromising CCPM concepts) to build ownership	Ø***********
CCPM implementation planned and executed like a project	Ø***********

Additional factors or clarifying comments: ____

(PAGE 14)

Presence of Factors that can be Attributed to Critical Chain Methodology

CCPM = critical chain project management

*Below are the factors that potentially impact the success rate of CCPM implementations in terms of the critical chain methodology. Please evaluate the degree of presence for each factor using the star rating scale.

1 star (not present)....2-10 stars (degrees of increasing presence)....11 stars (significant presence)

Desire for a CCPM standard	Ø***********
Satisfaction about the method for activity duration estimations	Ø***********
Satisfaction about the method used for buffer duration calculations	Ø***********
Conflict between leadership and the project team about task/buffer duration estimates	Ø***********
Difficulty in determining the correct baseline critical chain schedule	Ø***********
Tasks were frequently reprioritized	Ø***********
Management frequently interrupted work for updates	Ø***********
Focused work was possible (i.e., multitasking was eliminated)	Ø***********
Difficulty in coordinating with external suppliers	Ø***********
Delayed starts of non-critical chain (feeding) paths caused problems	Ø***********
Complexity of method caused problems	Ø***********
Earned Value Management (EVM) used in conjunction with CCPM	Ø***********
Project team members had non-project work	Ø***********
Lean methods used in conjunction with CCPM	Ø***********

Additional factors or clarifying comments: ____

(PAGE 15)
Optional Selection of Critical Chain Implementation Success and Failure Factors

Below are the factors (condensed) that were provided in the survey that can potentially impact the success or failure of a critical chain project management (CCPM) implementation. After careful consideration of each potential factor,

(1) select **five factors in the success column** that are most essential in achieving a successful CCPM implementation and
(2) select **five factors in the failure column** that are most detrimental and contribute to a failed CCPM implementation attempt.

	Success	Failure
Pre-existing: Industry Type	□	□
Pre-existing: Project Management Practices	□	□
Pre-existing: Size of Organization	□	□
Pre-existing: Use of Scheduling Techniques	□	□
Pre-existing: Project Attributes (uncertainty & number of tasks)	□	□
Pre-existing: Project Focus (cost, time, scope, or quality)	□	□
Primary Goal: "Try it out"	□	□
Primary Goal: Speed up Projects	□	□
Primary Goal: Create a Better Working Environment	□	□
Primary Goal: Directly affect the Bottom Line	□	□
Full Implementation using All CCPM Features	□	□
Partial Implementation using Only Some CCPM Features	□	□
Change Factor: Buy-In and/or Organizational Support (or lack of)	□	□
Change Factor: Resistance (or lack of)	□	□
Change Factor: Urgency (or lack of)	□	□
Change Factor: Leadership Support (or lack of)	□	□
Change Factor: Established Vision (or lack of)	□	□
Change Factor: Communication (or lack of)	□	□
Change Factor: Stakeholder Involvement (or lack of)	□	□
Change Factor: Software Integration/Functionality (or lack of)	□	□
Change Factor: Integration of Expert Knowledge in Team Structure (or lack of)	□	□
Change Factor: Training (or lack of)	□	□
Change Factor: Measurements of Implementation Success (or lack of)	□	□
Change Factor: Performance Management Reinforcing CCPM Behaviors (or lack of)	□	□
Change Factor: Customization Allowed to Build Ownership (or not allowed)	□	□
Change Factor: Implementation Planned as a Project (or lack of)	□	□
CCPM Factor: Lack of Critical Chain Standard	□	□
CCPM Factor: Complexity of Method	□	□

CCPM Factor: Multitasking Eliminated (or not eliminated)	◻	◻
CCPM Factor: Frequent Reprioritization of Tasks (or lack of)	◻	◻
CCPM Factor: Management Interruptions (or lack of)	◻	◻
CCPM Factor: Non-Project Work (or lack of)	◻	◻
CCPM Factor: Coordination with External Suppliers (or lack of)	◻	◻
CCPM Factor: Integration with Earned Value Management (or lack of)	◻	◻
CCPM Factor: Integration with Lean Methods (or lack of)	◻	◻

Other(s) (please elaborate):____

(PAGE 16)
Comments/Concerns
THANK YOU SO MUCH FOR PARTICPATING IN THIS SURVEY!
Your responses will help determine which factors influence the success rate of CCPM implementations.

If you have separate critical chain project management experiences to share, after completing this survey, please feel free to return to the beginning and complete the survey again.

As a follow-up to this survey, I will be conducting interviews to better understand the factors related to the success (or failure) of CCPM implementations. If you are interested in being part of the follow-up interview process, please contact me (Lisa Repp) at lisamrepp@yahoo.com.

Please provide any comments/concerns that you have related to the survey.
____

(FINISH SURVEY)
THANK YOU FOR TAKING THE TIME TO SHARE YOUR EXPERIENCES!
Your responses will help determine which factors influence the success rate of CCPM implementations.

If you would like to take the survey again for a separate CCPM implementation event, please use the following link: http://kwiksurveys.com?s=LOLNMM_f587ef06
Also, please forward the above survey link to anyone that might have had experience with CCPM implementations.

If you would like to view/track results of this survey, please use the following link:
http://kwiksurveys.com/results-overview.php?surveyID=LOLNMM_f587ef06&mode=4

As a follow-up to this survey, I will be conducting interviews to better understand the factors related to the success (or failure) of CCPM implementations. If you are interested in being part of the follow-up interview process, please contact me (Lisa Repp) at lisamrepp@yahoo.com.

APPENDIX D

INTERVIEW CONSENT FORM

CONSENT FORM

For Participation of Human Participants in Research
University of Wisconsin - Platteville

PURPOSE:
The interviews are being conducted to determine if there are any significant factors leading to success or failure that were present during the critical chain project management implementation in which you have had experience. The information provided will be categorized with factors that have already been determined using an extensive literature review. Additional factors that are identified in the interview will compared to survey results of this study and provide recommendations for future research.

PROCEDURE:
This is how the interview process will work:

1. Sign this Informed Consent Form
2. Set up an interview time with the researcher. There are three discussion prompts that will be used as follows:
   - Please describe your experience leading up to the decision to pursue critical chain project management implementation.
   - Continue with a description of your experiences related to all aspects of the critical chain project management implementation.
   - What factors during implementation of critical chain project management contributed to the success of the implementation?
3. Conduct the interview via a recorded phone conversation.
4. Complete the post-interview survey sent to a preferred e-mail address.

TIME REQUIRED:
The interview will take as long as needed to describe your implementation experience, with initial expectations for duration of approximately one hour. The post-interview survey will take approximately twenty minutes to complete.

RISKS:
It is not anticipated that this study will present any risk to you other than the inconvenience of the time taken to participate.

BENEFITS:
Your participation in the study will ensure the overall investigation into what factors influence critical chain project management implementation success (or failure) is comprehensive in nature. Factors that are indentified in the interview could directly impact the direction of future research into the topic.

YOUR RIGHTS AS A PARTICIPANT:

The information gathered in this study will be used in a confidential form. A thesis research paper and summary research paper for publication will be written in which data or summarized results will not be released in any way that could identify you or the organization in which you are affiliated. If you want to withdraw from the study at any time, you may do so without penalty or repercussions. The information from you up to that point would be destroyed if you so desire.

If you have any questions after participating in the study, please ask your experimenter or contact:

Lisa Repp, Researcher
lisamrepp@yahoo.com

OR

Dr. Scott Wright, Faculty Sponsor
Department of Project Management
University of Wisconsin-Platteville
(608) 342-1411
wrightsc@uwplatt.edu

Once the study is completed, you may request a summary of the results by contacting the above researcher or faculty sponsor.

CONCERNS:
If you have any concerns about your treatment as a participant in this study, please call or write:

Kathryn Lomax, Director
Office of Sponsored Programs
(608) 342-1456; lomax@uwplatt.edu

I have read the above information and willingly consent to participate in this research.

Signed ____ Date __________________